COHERENT

User Manual

PowerMax™-USB/RS

Sensor System

COHERENT

User Manual
PowerMax-USB/RS
Sensor System

COHERENT®
27650 SW 95th Ave.
Wilsonville, OR 97070

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In the U.S.:

Should you experience difficulties with your product, or need technical information, please visit our website: www.Coherent.com. You can obtain additional support by either telephoning our Technical Support Hotline at 1.800.343.4912, or e-mailing our Support Team at support.instruments@Coherent.com. Telephone coverage is available Monday through Friday (except U.S. holidays).

If you call outside our office hours, your call will be taken by our answering system and will be returned when the office reopens.

If there are technical difficulties with your product that cannot be resolved by support mechanisms outlined above, please e-mail or telephone Coherent Technical Support with a description of the problem and the corrective steps attempted. When communicating with our Technical Support Department, via the web or telephone, the model and serial number of the product will be required by the Support Engineer responding to your request.

Outside the U.S.:

If you are located outside the U.S., visit our website for technical assistance, or telephone our local Service Representative. Representative phone numbers and addresses can be found on the Coherent website, www.Coherent.com.

Coherent provides web and telephone technical assistance as a service to its customers and assumes no liability thereby for any injury or damage that may occur contemporaneous with such services. These support services do not, under any circumstances, affect the terms of any warranty agreement between Coherent and the buyer. Operating a Coherent product with any of its interlocks defeated is always at the operator's risk.

TABLE OF CONTENTS

Preface vii
RoHS Compliance vii
U.S. Export Control Laws Compliance vii
Publication Updates vii
Symbols Used in This Document vii

Safety 1
Waste Electrical and Electronic Equipment (WEEE, 2002) 1
Declaration of Conformity 2

Description 3
Introduction 3
Product Overview 3
Product Features 3
Software Features 4
Technical Description 5
Thermopile Technology 5
Long-Pulse Energy Measurement With a Thermopile 6
Semiconductor Technology 7
Applying Wavelength Compensation Accuracy 9

Operation 11
LED Status Indicators 11
PowerMax-USB LED Lights 11
PowerMax-RS LED Lights 12
Powering PowerMax-RS Sensors 12
Extending Cable Length 12
How to Take a Power Measurement 13
Measuring Power With a PowerMax-USB Thermopile Sensor 13
Measuring Power With a PowerMax-RS Thermopile Sensor 16
Zeroing 18
Setting the Wavelength 18
Using the Software 19
Front Panel 19
Keyboard Shortcuts 19
Select Sensor 20
Start/Stop Data Collection 21
Trending Chart 22
Histogram Chart 23
Tuning Chart 24
Alignment Target Chart 25
Synchronized Trending Chart 26
Reset Error 28
Graph Palette 29

Live Reading 30
Wavelength 30
Live Data Averaging 31
Mean 31
Min 32
Counts 32
Std Dev 33
Max 34
Mode 34
Sample Collection 35
Sample Size 35
Zero Sensor 36
Reset Button 36
Gain Correction 37
Collection Mode 38
Collection Interval 38
Log Data to File 39
Log Data File 39
Menus 40
File Menu 40
Settings Menu 45
View Menu 47
Window Menu 49
Help Menu 49

Host Interface 51
Introduction 51
Message Terminators 52
Messages Received by the Sensor 52
Messages Sent by the Sensor 52
Host Command Quick Reference 53
SCPI Interface Section 55
Syntax and Notation Conventions 55
Commands and Queries 56
SCPI Common Commands 56
System Options 56
Error Record Reporting and Collection 58
Measurement Setup and Control 60
Querying Measurement Data 62
Sensor Information 63
Legacy LaserPAD/SSIM Interface Section 65
Commands and Queries 65
LaserPAD/SSIM Streaming Data Record Format 69
Data Streaming Transmission Interface Section 70
Streaming Measurement Data 70
Commands and Queries 70
Operational Parameters 71

Calibration and Warranty 73
Calibration 73
Coherent Calibration Facilities and Capabilities 73
Limited Warranty 74
Extended Warranty 74
Warranty Limitations 75
Obtaining Service 75
Product Shipping Instructions 76

Appendix A: Specifications 77
Compatible Sensors 77

Appendix B: Troubleshooting and Error Messages 79

Index 81

LIST OF TABLES

1. Wavelength Compensation Accuracy 10
2. PowerMax-USB LED Light Conditions 11
3. PowerMax-RS LED Light Conditions 12
4. Keyboard Shortcuts 19
5. Host Command Quick Reference 53
6. Status Condition Character Definitions 56
7. Error Codes and Description Strings 58
8. Measurement Data Record Formats 62
9. Flags Character Definitions 63
10. Measurement Data Record Formats 69
11. Data Streaming Transmission Rates 71
12. Operational Parameters 71
13. Coherent Service Centers 76
14. Compatible Sensors 77

LIST OF FIGURES

1. Waste Electrical and Electronic Equipment Label 1
2. Saturation Power and Minimum Power for PowerMax-USB UV/VIS Quantum Sensor ... 8
3. Photo Sensitivity Temperature Characteristics 9
4. RV Spectral Correction for Thermal Sensors (Normalized to Calibration Wavelength) ... 10
5. Front Panel 19
6. Drop-Down Menus 40
7. File Menu 40
8. Settings Menu 45
9. View Menu 47
10. Window Menu 49
11. Help Menu 49

Preface

This manual contains user information for the Coherent PowerMax™ meterless power sensors and the PowerMax PC software.

RoHS Compliance

This Coherent product is RoHS compliant.

U.S. Export Control Laws Compliance

It is the policy of Coherent to comply strictly with U.S. export control laws.

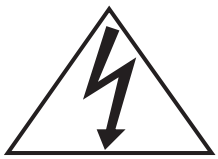
Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification should be obtained from Coherent or an appropriate U.S. Government agency.

Publication Updates

To view information that may have been added or changed since this publication went to print, connect to www.Coherent.com.

Symbols Used in This Document

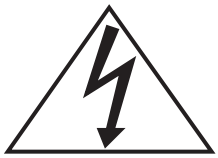


This symbol is intended to alert the operator to the presence of dangerous voltages associated with the product that may be of sufficient magnitude to constitute a risk of electrical shock.

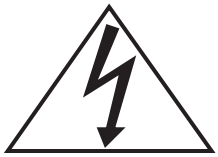
This symbol is intended to alert the operator to the presence of important operating and maintenance instructions.

SAFETY

Carefully review the following safety information to avoid personal injury and to prevent damage to this product or any equipment connected to it. There are no user-serviceable parts in Coherent PowerMax meterless power sensors. For service information, refer to "Obtaining Service" on page 75.



Do not operate the system if its panels are removed or any of the interior circuitry is exposed.



Do not operate the system in wet or damp conditions, or in an explosive atmosphere.

Do not operate the system if there are suspected failures. Refer damaged units to qualified Coherent service personnel.

Waste Electrical and Electronic Equipment (WEEE, 2002)

The European Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) is represented by a crossed-out garbage container label (Figure 1). The purpose of this directive is to minimize the disposal of WEEE as unsorted municipal waste and to facilitate its separate collection.

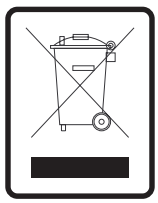


Figure 1. Waste Electrical and Electronic Equipment Label

Declaration of Conformity

D137898 Revision AA

Declaration of Conformity

We

Coherent, Inc.
27650 SW 95th Ave
Wilsonville, Oregon, USA 97070

declare under sole responsibility that

PowerMax USB and **PowerMax RS**

meet the intent of Directive 2004/108/EC for Electromagnetic Compatibility. Compliance was demonstrated per testing to EN61326-1:2006 Electromagnetic Compatibility Product Family Standard for Measurement, Control and Laboratory Equipment to include the following test specifications as of August 2009:

EN55011:2007 Class A Radiated Emissions
EN55011:2007 Class A Conducted Emissions
EN61000-3-2:2000 Powerline Harmonics
EN61000-3-3:1995/A1:2001/A2:2005 Powerline Voltage Fluctuation and Flicker
IEC61000-4-2:2001 Electrostatic Discharge – Performance Criteria B
EN61000-4-3-A1:2008 Radiated Immunity – Performance Criteria A
EN61000-4-4:2004 Electrical Fast Transient Immunity - Performance Criteria B
EN61000-4-5:2006 Electrical Slow Transient Immunity- Performance Criteria B
EN61000-4-6-Ed3:2008 Conducted RF Immunity - Performance Criteria A
EN61000-4-11:2006 Power Line Dropout

Director of Engineering Date: 10/1/09

Director, LSM Date: 10/1/09

Coherent, Inc. Page 1 of 1

DESCRIPTION

Introduction

Coherent PowerMax-USB and PowerMax-RS sensors are the world's first laser power sensors that utilizes state of the art micro-electronics miniaturization techniques and integrate an entire instrument within a USB 2.0 or RS-232 cable connector. Specifically, PowerMax-USB and PowerMax-RS sensors have all the signal processing and power measurement electronics normally contained in a LabMax meter and connect directly to a PC with plug-and-play functionality. Ideally suited for low- and high-volume embedded sensor applications, Coherent's new family of sensors eliminates the need for a separate meter box, thus delivering a significant savings in cost and space, but with no reduction whatsoever in performance.

This measurement platform can also be used to measure the energy in a long laser pulse—typically greater than 1 millisecond in pulse width—by integrating the output of a thermopile sensor.

Coherent's PowerMax PC application software provides a virtual instrument interface for sensors that enable the operator to take laser power readings, log data, and compute measurement statistics. Users can also write their own software using host interface commands that control all aspects of power meter operation.

For the first time, separate electronics are no longer required between the sensor and a PC. For those customers who can use a PC for monitoring laser power, these sensors offer significant cost savings, space savings, and no reduction in performance.

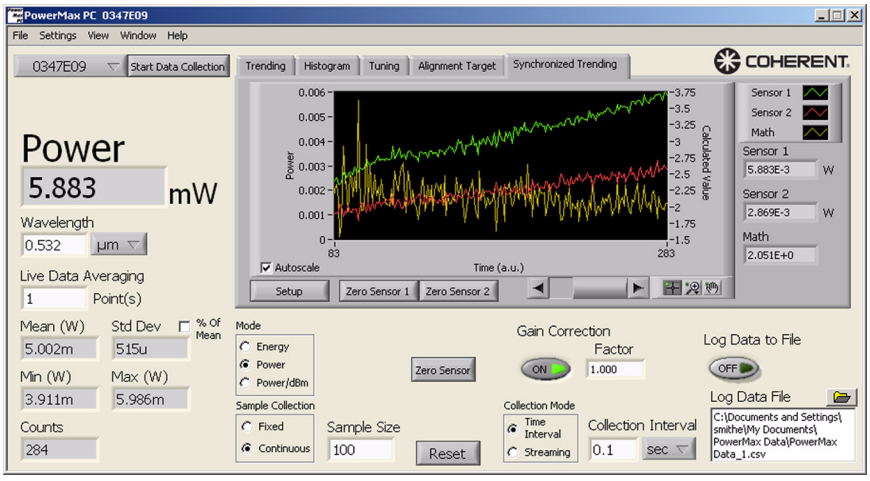
Product Overview

Product Features

- PowerMax-USB provides direct USB 2.0 connection to a PC. Power is provided via USB connection.
- PowerMax-RS provides RS-232 connectivity. Power input is provided by a +5VDC input (power supply is available as an optional accessory).
- Instrumentation platform is compatible with thermopile and optical sensors and can be adapted to most power sensors that Coherent manufactures.

- Displays beam position with position-sensing quadrant thermopiles (such as LM-model sensors like the LM-10).
- High resolution 24-bit A/D converter supports four digits of resolution and measurement accuracy equivalent to that found in Coherent's LabMax meters.
- Sensors include spectral compensation for accurate use at wavelengths that differ from the calibration wavelength. Each sensor receives a unique spectral compensation curve specific to the responsivity of its specific element, as well as transmission characterization of any associated optics.
- Thermopile sensors include a speed-up algorithm that speeds up the natural response of the thermopile detector without overshoot.
- LED status indicators inside USB and RS-232 connectors provide health-and-status information.
- Thermopile sensors offer long-pulse joules capability.

Software Features



Plug-and-play application software is supplied standard and includes the following features:

- Trending
- Statistics (mean, minimum, maximum, and standard deviation) and log batch to file.
- Tuning
- Display beam position on position-sensing thermopiles and log results to file
- Histogram
- Simultaneously operate multiple sensors

- Perform synchronized ratiometery (A/B analysis). Trend and log results to file.
- For LaserPAD or SSIM customers, the host command set includes drop-in compatibility.

For system integrators and for implementations involving customer-written software, the sensors incorporate a comprehensive command set that is easy to access:

- Utilized a Window USB driver and supports simple ASCII host commands for remote interfacing using both PowerMax-USB and PowerMax-RS sensors.
- Using customer-written software, the remote interfacing host command set allows sensors to be remotely controlled.
- National Instruments™ LabVIEW™ driver is supplied for easy LabVIEW integration.

Technical Description

Thermopile Technology

Thermopile sensors are a great all-purpose technology suitable for many lasers. They are used for measuring CW laser power, average power in pulsed lasers, and are often used to integrate the energy of long pulses. Thermopile sensors absorb incident laser radiation and convert it into heat. This heat ultimately flows to a heat sink that is held at ambient temperature by either convection-cooling or water-cooling. The temperature difference between the absorber and the heat sink is converted into an electrical signal by a thermocouple junction.

Thermopiles operate across a wide range of input powers, and unlike a photodiode-based sensor they will not saturate. The spectral range is dependent upon the coating applied to absorb the laser power. The coating used on many thermopiles is broadband in nature and is relatively flat from the ultraviolet through the infrared.

These sensors have natural response times on the order of several seconds for a low power sensor and up to one minute for a kilowatt sensor. The exponential nature of the natural thermopile output allows one to electronically accelerate the voltage to its final value ahead of the actual sensor signal using a software algorithm. We typically call this capability a “speed-up” algorithm. When combined with the PowerMax-USB and PowerMax-RS circuitry, a

speed-up algorithm can be applied to provide a much faster response—on the order of seconds or less for most thermopile sensors. This feature can be turned on and off in the software.

Coherent has two main types of thermopile sensors:

- The *LM Model* line utilizes a unique thermopile disk in which the thermocouples are split into four quadrants, allowing the sensors to provide beam position information in addition to power measurement.
- The *PM Model* line incorporates traditional thermopile disks that provide power measurement without beam position information.

PowerMax-USB and PowerMax-RS sensors can use both types of sensors.

Long-Pulse Energy Measurement With a Thermopile

Thermopile sensors are most commonly used for average power measurements on pulsed and CW lasers. A unique capability of thermopile sensors is the ability to integrate the power of a single "long" laser pulse (*long pulse* refers to pulses roughly 1 millisecond up to several seconds in pulse length). The instrumentation analyzes the output of the thermopile and applies the integration through the use of an algorithm that results in a Joules reading. This allows the thermopile to measure the energy of single pulses between 1 millisecond and 10 seconds in length, and with energies from millijoules to

hundreds of Joules. The measurement accuracy of this mode is typically better than ± 3% when performed with PowerMax-USB and PowerMax-RS sensors.

This capability is very useful for what are commonly called long-pulse medical or industrial type lasers. Common applications for this type of measurement are in the medical field—especially skin resurfacing and hair removal—and in material processing applications, such as laser welding. These laser systems often utilize high-energy lasers that have large beam sizes and relatively long pulses.

This type of measurement requires careful selection of the appropriate power sensor, based upon the laser pulse being measured. A good "rule of thumb" for using a thermopile for this type of measurement is to compare the maximum pulse energy you need to measure (in Joules) with the maximum power rating of a sensor (in Watts).

Often times a sensor like the PM150-50C is ideal for these measurements. It features a large 50 mm aperture size, can handle pulse energies up to 150J, and can be used air-cooled for single pulse energy measurements. A PM150-50C normally needs to be water-cooled for continuous power measurements. The PS19Q sensors, on the other hand, allow long-pulse measurements down into the mJ level.

Thermopile joules mode specifications for several PowerMax-USB and PowerMax-RS sensor can be found in Table 14 on page 77. For an up-to-date list of all compatible sensors and their specifications, visit out website: www.Coherent.com/LMC.

Semiconductor Technology

Semiconductor photodiode-based sensors convert incident photons into current that can be measured by our instrumentation. We typically refer to these devices as *optical sensors* or *quantum sensors*. The photodiodes used in these types of sensors offer high sensitivity and low noise, enabling them to detect very low light levels. The UV/VIS optical sensor in the PowerMax-USB line is designed to measure power of CW sources, as well as the average power of pulsed sources, as long as the repetition rate is above 100 pps. Photodiodes also have a fast response time, making this senor convenient for tuning and peaking lasers.

These types of sensors have several orders of magnitude higher sensitivity than thermopile sensors and are quite stable. They do, however, suffer from photocurrent saturation. The UV/VIS sensor incorporated into the PowerMax-USB product line includes an attenuating filter that allows the sensor to be used into the hundreds

of milliwatt level without saturation. This ND filter, and the light shield threaded onto the front of the sensor, also help to block stray light, thereby resulting in a lower noise floor.

We incorporate spectral compensation in the PowerMax-USB and PowerMax-RS UV/VIS sensor to provide accurate measurements across the 325 to 1065 nm spectrum. Because the spectral response of the ND filter and photodiode varies significantly across this wavelength range, it is important to check the maximum measurable power at the wavelength of use to make sure the sensor is not being saturated. Figure 2, below, indicates the maximum and minimum measurable power levels by wavelength.

The following curve plots the maximum measurable power—which is the saturation level of the photodiode—as well as the minimum recommended power level, by wavelength.

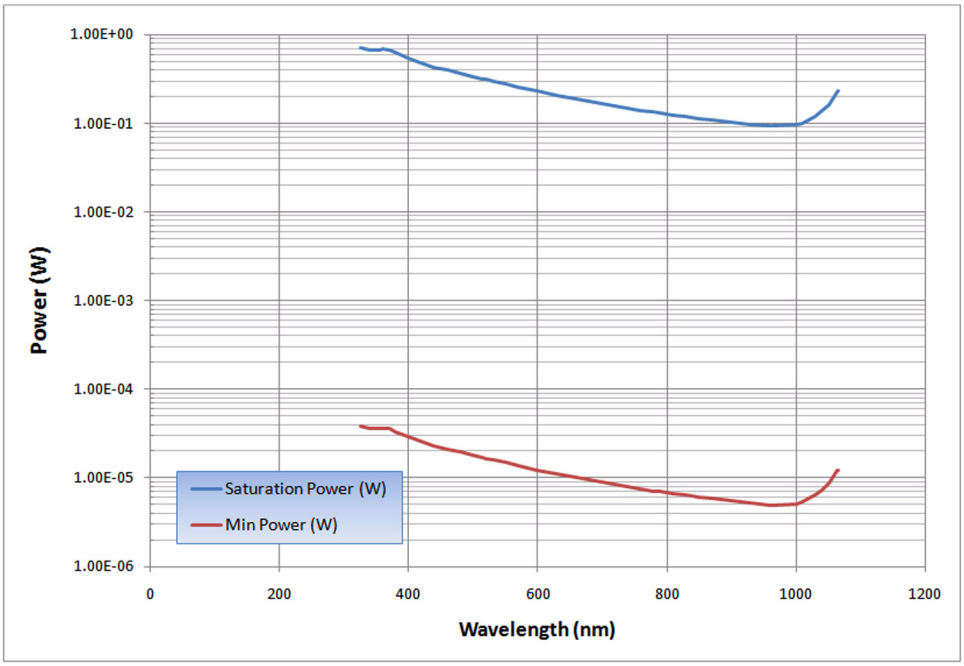


Figure 2. Saturation Power and Minimum Power for PowerMax-USB UV/VIS Quantum Sensor

UV/VIS Temperature Linearity: Like all silicon photodiodes, the UV/VIS Quantum sensor has temperature sensitivity in the infrared region. At 1064 nm, for example, it has a 0.5%/ºC thermal coefficient. Due to the electronics inside the sensor, measurement error of up to 2% is present at 1064 nm after a 10-minute warm-up time. Additional error can be present if the ambient measurement environment differs from the calibration wavelength listed on the calibration certificate.

In practice, wavelengths shorter than 1000 nm have insignificant effects due to temperature.

The following figure references the thermal coefficient at the wavelength of use.

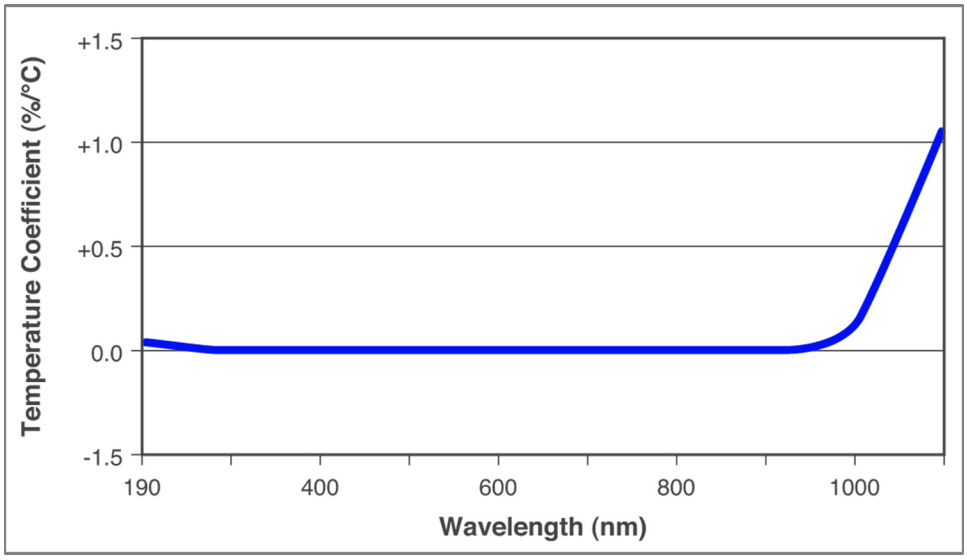


Figure 3. Photo Sensitivity Temperature Characteristics

Applying Wavelength Compensation Accuracy

Overall measurement accuracy is a combination of:

- Calibration uncertainty. Note: Specifications for several sensors are available in Table 14 on page 77. For an up-to-date list of all compatible sensors and their specifications, visit out website: www.Coherent.com/LMC.
- Wavelength compensation accuracy (refer to Table 1 on page 10).

The combined accuracy is based upon practices outlined in the *National Institute of Standards Guidelines for Evaluating and Expressing Uncertainty* (NIST Technical Note 1297, 1994 Edition). The combined accuracy of the measurement is calculated by using the law of propagation of uncertainty using the "root-sum-of-square" (square root of the sum of squares), sometimes described as "summing in quadrature" where:

Measurement Accuracy = $\sqrt{U^2 + W^2}$

where:

U = Percent Calibration Uncertainty
W = Wavelength Accuracy

Example:

PowerMax-USB LM-10 used at 1064 nm

U = 2%
W = 1.5%

Measurement Accuracy = $\sqrt{2^2 + 1.5^2} = \sqrt{4 + 2.3} = 2.5\,\%$

Coherent uses three primary coatings to capture the incident radiation on our thermal sensors. The specifications for each sensor list which coating is used. Typical wavelength ranges and response curves for these coatings are shown in Figure 4, below. Each sensor contains a spectral curve generated from reflectance measurements taken with spectrometers. The reflectance data are converted into a wavelength compensation look-up table that is loaded into the sensor. This data is accessed by selecting a wavelength of operation in the software.

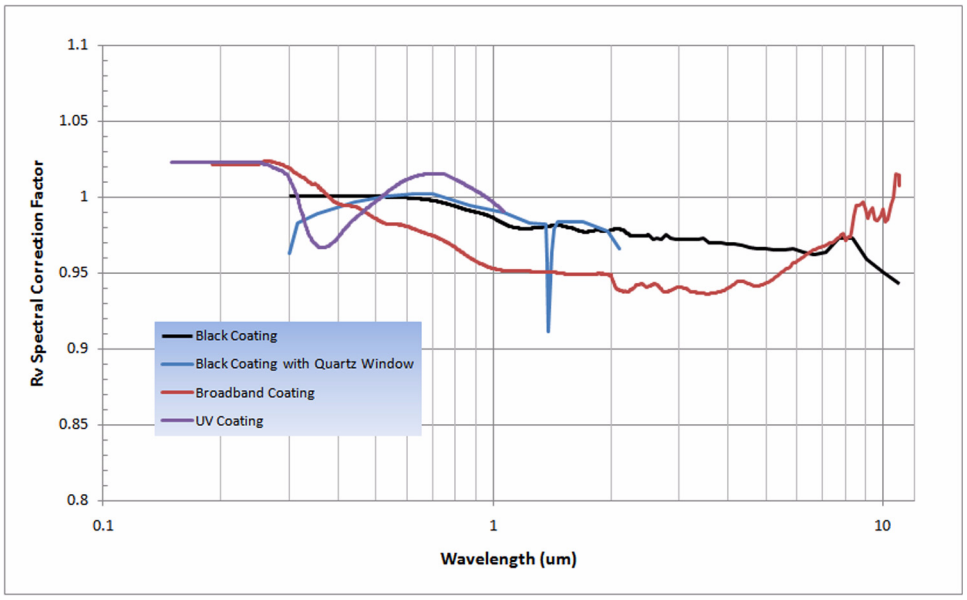


Figure 4. RV Spectral Correction for Thermal Sensors (Normalized to Calibration Wavelength)

Table 1 lists the spectral compensation accuracy for each type of sensor.

Table 1. Wavelength Compensation Accuracy

SENSOR	Wavelength Compensation Accuracy[a]	CALIBRATION WAVELENGTH (nm)
All PM- and LM-model thermopiles	± 1.5%	10600
PS model	± 1.5%	514
UV/VIS optical model	± 4% (325 to 900 nm) ± 5% (900 to 1065 nm)	514

a. Refers to wavelengths other than the calibration wavelength.

OPERATION

In this section:

- LED status indicators (this page)
- Powering PowerMax-RS sensors (page 12)
- Extending cable length (page 12)
- How to take a power measurement (page 13)
- Zeroing (page 18)
- Setting the wavelength (page 18)
- Using the software (page 19)

LED Status Indicators

Blue LED lights are contained within the PowerMax-USB and PowerMax-RS connectors to provide health-and-status information.

PowerMax-USB LED Lights

Table 2. PowerMax-USB LED Light Conditions

LED LIGHT CONDITION	STATUS
No light visible	If the PowerMax-USB sensor is connected to the PC but there are no visible lights, the sensor is not powering up properly. Test the sensor on another USB port and if that does not solve the problem, contact Coherent for service (refer to Table 13 on page 76 for contact information).
Lights flashing slowly (0.5 Hz)	Sensor is functioning; however, the driver has not been properly loaded. First, make sure power is being properly applied to the USB port. If that does not solve the problem, remove the sensor from the USB port and reinstall the software from the CD that shipped with the product (or download the latest software from our website: www.Coherent.com).
Lights slowing ramping up and down in intensity	Sensor is functioning and the driver has been properly loaded.
Lights flashing fast (10 Hz)	The sensor is taking power measurements and sending data over the host port.

PowerMax-RS LED Lights

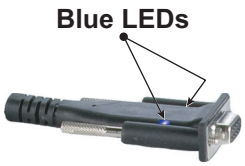
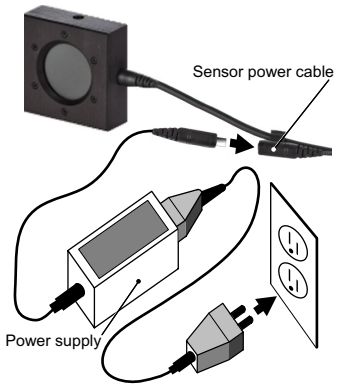


Table 3. PowerMax-RS LED Light Conditions

LED Light Condition	Status
No light visible	If + 5VDC has been applied to the PowerMax-USB sensor but there are no visible lights in the connector, the sensor is not powering up properly. Contact Coherent for service (refer to Table 13 on page 76 for contact information).
Lights slowing ramping up and down in intensity	Power has been applied to the sensor and it is functioning.
Lights flashing fast (10 Hz)	The sensor is taking power measurements and sending data over the host port.

Powering PowerMax-RS Sensors

The PowerMax-RS sensor is powered via a +5 VDC power supply input.



Extending Cable Length

USB sensors: The PowerMax-USB cable is 2.5 meters in length. USB hubs can be employed to extend the length of the cable. The USB standard allows for up to five hubs—connected in series with 5-meter cables connecting the hubs—thus providing a maximum range of 27.5 meters.

There are also active 5-meter USB extension cables on the market that perform as if they were a USB hub, but for just a single USB sensor. (Feel free to contact Coherent for advice related to particular hubs we have tested in-house.)

RS sensors: The RS cable is 300 mm in length. It is intended to be used with a standard off-the-shelf RS-232 extension cable to extend the length.

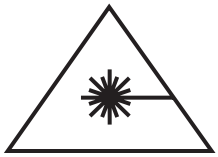
How to Take a Power Measurement

This section presents two "mini-tutorials" that explain how to connect a PowerMax-USB or PowerMax-RS sensor to your PC and begin taking measurements using the PowerMax PC software.

For instructions on communicating with the sensor directly via host commands, refer to "Host Interface" on page 51.

Tutorials include:

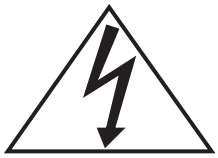
- Measuring power with a PowerMax-USB thermopile sensor.
- Measuring power with a PowerMax-RS thermopile sensor.



Follow all laser safety procedures. The laser must be switched OFF or shuttered before running the tutorials presented in this section.

Measuring Power With a PowerMax-USB Thermopile Sensor

This tutorial describes how to take a power measurement using a PowerMax-USB thermopile sensor.



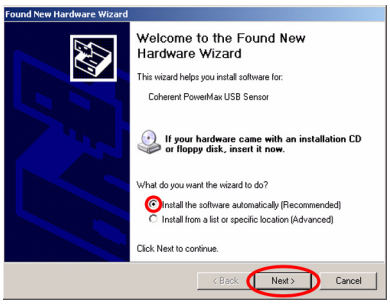
Verify the laser is switched OFF or shuttered before starting this tutorial.

---

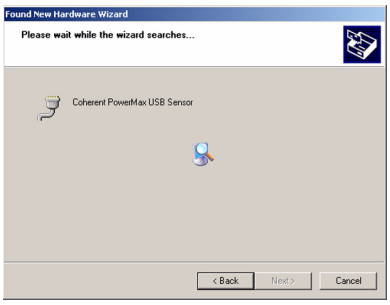
1. Install the PowerMax PC software (for detailed installation instructions, refer to the *PowerMax-USB/RS Software Installation and Quick Start Guide*—part number 1169931—that shipped with your system).

2. Plug in the PowerMax-USB sensor.

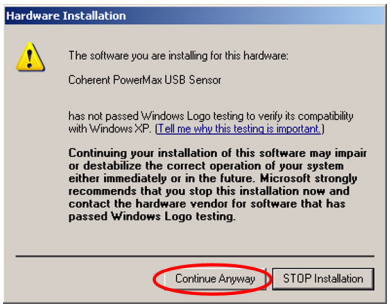
3. When the Found New Hardware Wizard screen appears, click "Install the software automatically (Recommended)" and then click the **Next** button to continue.


Found New Hardware Wizard
Welcome to the Found New Hardware Wizard
This wizard helps you install software for:
Coherent PowerMax USB Sensor
If your hardware came with an installation CD or floppy disk, insert it now.
What do you want the wizard to do?
Install the software automatically (Recommended)
Install from a list or specific location (Advanced)
Click Next to continue.
< Back
Next >
Cancel

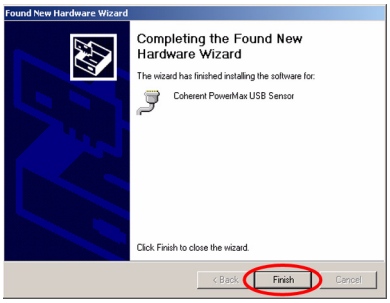
This screen display while the installation program searches for the PowerMax-USB sensor.



4. Click the **Continue Anyway** button to proceed with the installation.


Hardware Installation
The software you are installing for this hardware:
Coherent PowerMax USB Sensor
has not passed Windows Logo testing to verify its compatibility with Windows XP. (Tell me why this testing is important.)
Continuing your installation of this software may impair or destabilize the correct operation of your system either immediately or in the future. Microsoft strongly recommends that you stop this installation now and contact the hardware vendor for software that has passed Windows Logo testing.
Continue Anyway
STOP Installation

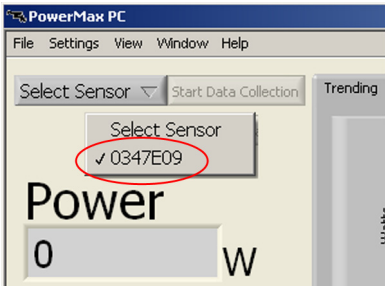
5. Click **Finish** to complete the installation.


Found New Hardware Wizard
Completing the Found New Hardware Wizard
The wizard has finished installing the software for:
Coherent PowerMax USB Sensor
Click Finish to close the wizard.
< Back
Finish
Cancel

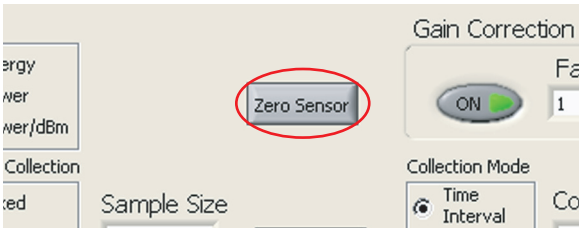
6. Confirm the blue LEDs on the USB connector are lit and slowly ramping up and down in intensity (which signifies the sensor is working and the driver is properly loaded).

7. Run the PowerMax PC software.

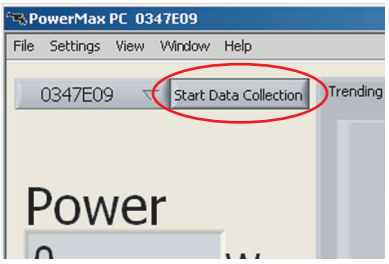
8. Select the sensor serial number from the Select Sensor dropdown menu. In the example at right, the selected sensor serial number is *0347E09*.



9. Press the **Zero Sensor** button to zero out any offset in the sensor.

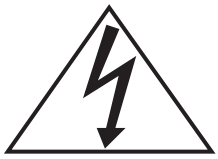


10. Press the **Start Data Collection** button and then turn ON the laser to begin taking power measurements.



Measuring Power With a PowerMax-RS Thermopile Sensor

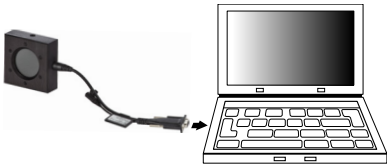
This tutorial explains how to take a power measurement using a PowerMax-RS thermopile sensor.



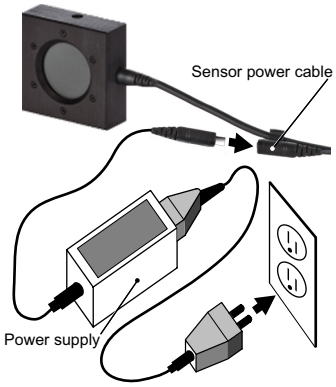
Verify the laser is switched OFF or shuttered before starting this tutorial.

1. Install the PowerMax PC software (for detailed installation instructions, refer to the "Software Installation" section of the *PowerMax-USB/RS Software Installation and Quick Start Guide*—part number 1169931—that shipped with your system).

2. Plug the PowerMax-RS sensor into an available RS-232 COM port on the computer.



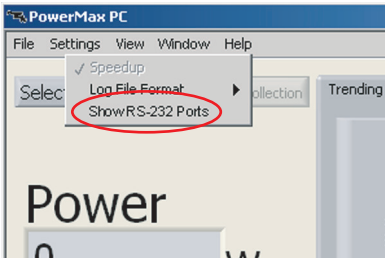
3. Plug the +5V DC power supply cable into the sensor power cable and the power supply into a wall electrical outlet. (The power supply is available from Coherent as an optional accessory—part number 1105557.)



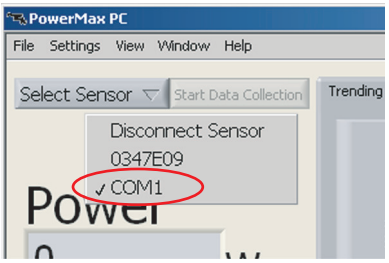
4. Confirm the blue LEDs on the RS connector are lit and slowly ramping up and down in intensity (which signifies the sensor is working and the driver is properly loaded).

5. Run the PowerMax PC software.

6. Click **Show RS-232 Ports** from the Settings dropdown menu. The software will scan COM ports for PowerMax-RS sensors.



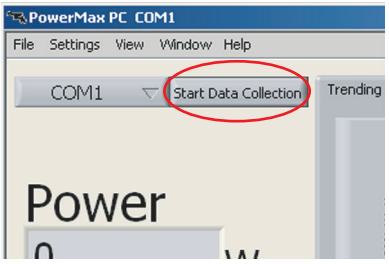
7. Select the COM port to which the PowerMax-RS sensor is attached. In the example at right, the selected COM port is *COM1*.



8. Insert the sensor into the beam path, *making sure the laser is turned OFF or shuttered until the sensor is zeroed*.

9. Press the **Zero Sensor** button to zero out any offset in the sensor.

10. Press the **Start Data Collection** button and then turn ON the laser to begin taking power measurements.



Zeroing

Pressing the Zero button implements the Zero function and sets the current sensor input as the baseline for future measurements. *It is recommended that you zero the sensor after first turning it on and before beginning any new set of power measurements.*

When a zero procedure is in process, no other button events are queued or activated until the procedure ends. The zero procedure immediately terminates if the sensor is disconnected or if an error is encountered.

Normally you should press the Zero button while the laser is turned off, or while the laser beam is blocked. If a finite power level is present at the sensor, the instrumentation will attempt to null it out.

The sensor can only zero a finite level of offset equivalent to approximately 10% of full scale range.

If zeroing is unsuccessful—which means that the power input is too large to null—re-zero in a more stable environment or select a different range.

Setting the Wavelength

The wavelength should always be set for accurate power measurements. This can be done either in the PowerMax PC application software or over the host port via a host command.

Using the Software

Front Panel

The Front panel (shown in Figure 5) is the first screen that appears once the software is launched. From here you can enter parameters, select modes, change ranges, start/stop data acquisition, and view the output in a chart format.

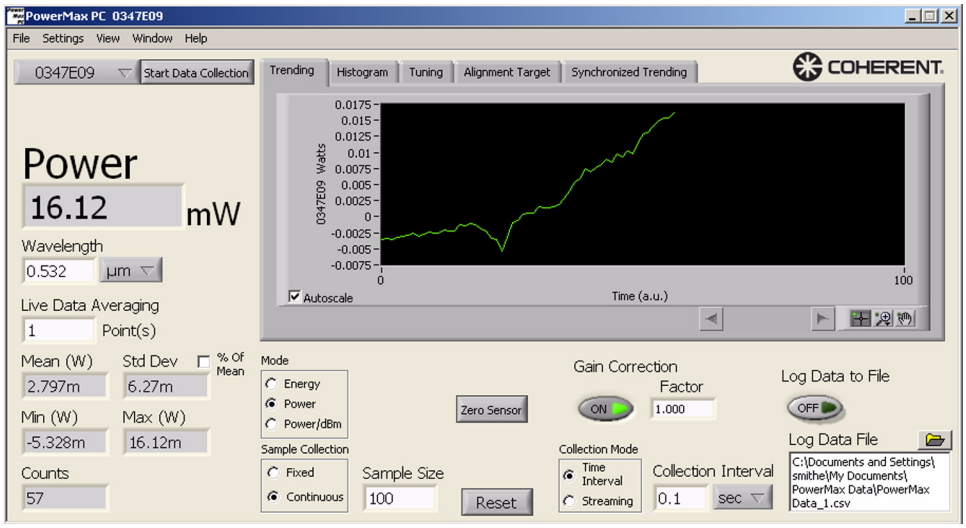


Figure 5. Front Panel

Individual functions accessed through the Front panel are discussed, starting next.

Keyboard Shortcuts

The following table shows available shortcuts for several standard functions:

Table 4. Keyboard Shortcuts

FUNCTION	SHORTCUT
Exit program	<Ctrl>+<Q>
Open new Front panel	<Ctrl>+<N>
Print window	<Ctrl>+<P>
Show context help	<Ctrl>+<H>
View full application	<Ctrl>+<F>
View saved data file	<Ctrl>+<V>

Select Sensor

Lists all the connected PowerMax sensors that can be selected for use by the current Front panel.

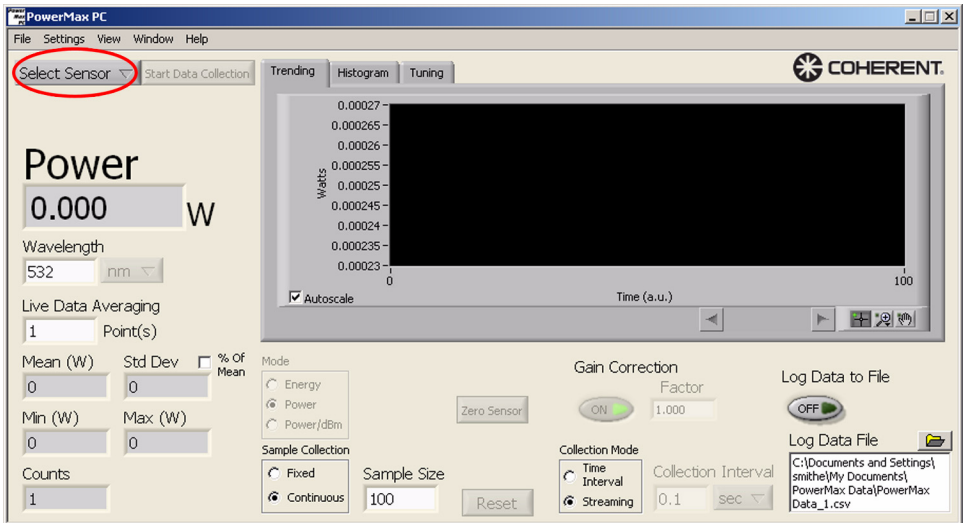
The serial numbers of all attached PowerMax sensors are shown in the dropdown menu, with the visible serial number indicating which sensor is the current data source.

(*USB sensors*) The serial numbers of all attached PowerMax-USB sensors are shown in the dropdown menu, with the visible serial number indicating which sensor is the current data source.

(*RS sensors*) RS-232 COM port numbers will appear in the drop-down menu if RS-232 ports are enabled on the Settings dropdown menu.

Notes:

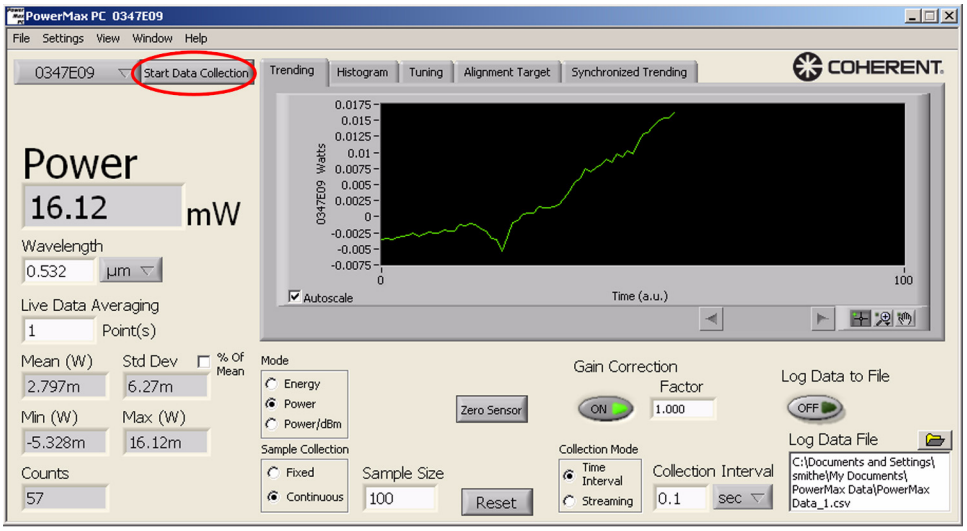
- After attaching a sensor, it may take several seconds for the serial number to appear on the list.
- Sensors connected to your computer but already controlled by a Front panel will appear grayed out (not selectable) in the Select Sensor dropdown list. If you de-select a sensor in a Front panel, the Select Sensor dropdown list automatically updates and that sensor will then be available for selection.
- By default, RS-232 ports do not automatically appear on this dropdown menu.



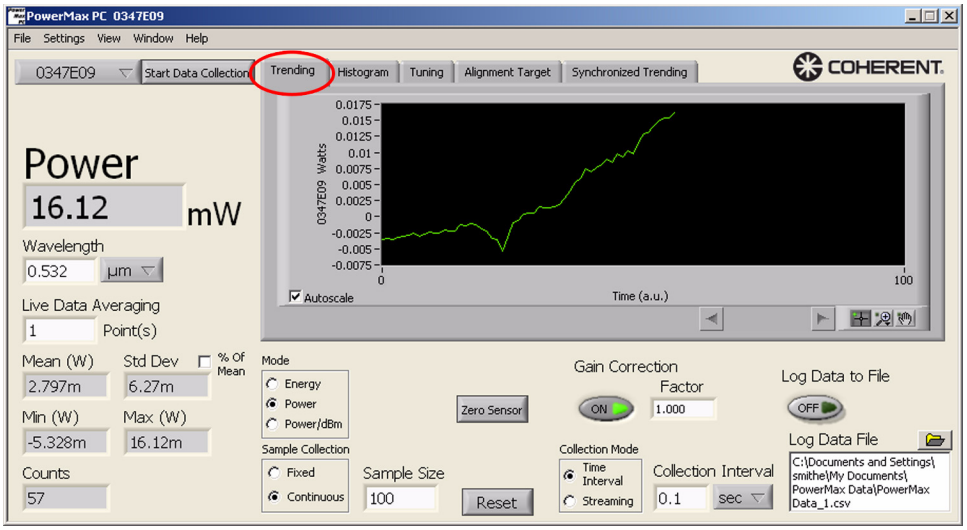
Start/Stop Data Collection

Enables/disables sample collection, including:

- The Trending chart
- Synchronized trending, if enabled
- The Histogram chart
- The Tuning chart
- The Position indicator
- The Reading indicator
- All statistic indicators
- Data logging, if active



Trending Chart Displays the data received from the PowerMax sensor.



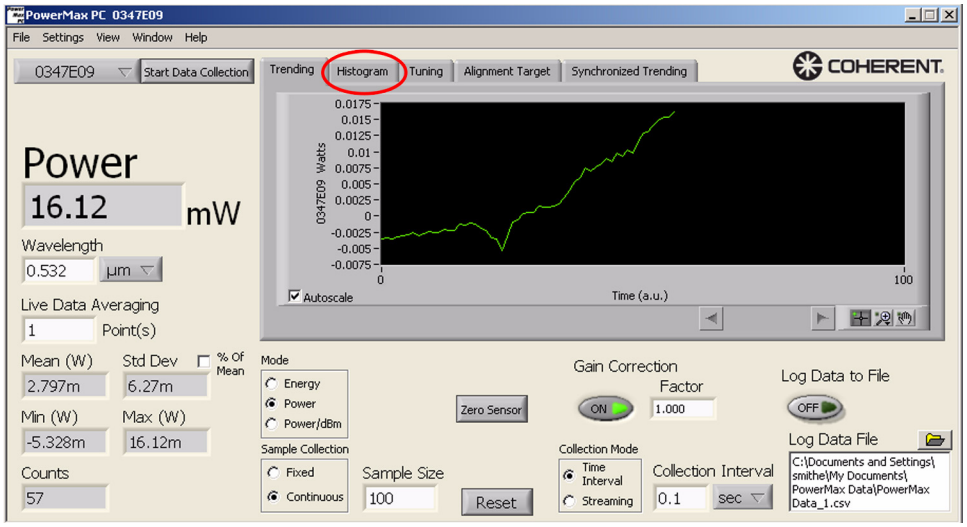
The axis scale points—(x) and (y)—can be directly edited by clicking on them and entering the desired value. Example: Clicking on the first x-axis point and setting it to 0 (zero) displays the data from beginning to present.

Autoscale

- Checked: Y-axis Autoscale is active.
- Unchecked: The graph displays the y-axis in fixed scale.

Histogram Chart

Displays a histogram of measurement values in the sample buffer. The sample buffer is controlled by the Sample Size. For example, with a sample size of 100, up to 100 samples are used in the histogram. Once more than 100 samples have been collected, only the 100 most recent samples are displayed.



Number of Bins

Sets the number of bins along the x-axis used to plot the histogram data.

Tuning Chart

Displays two values on the Tuning meter:

- **Green** pointer = current measurement value (also displayed as a value in the Current Value window at the bottom left of the Tuning chart)
- **Red** pointer = maximum measured value (also displayed as a value in the Maximum window at the bottom right of the Tuning chart)

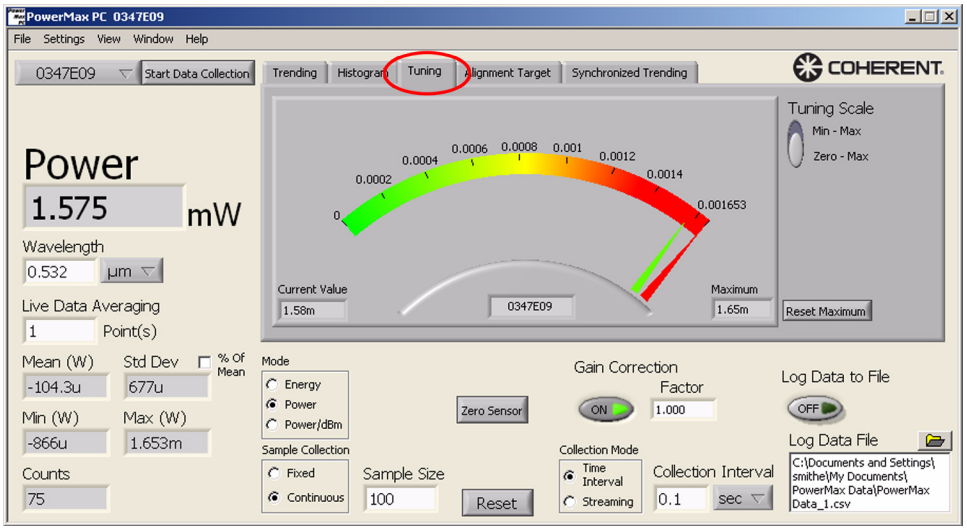
Tuning Scale

Use this button to select the scaling range of the Tuning meter.

- Min - Max: Sets the low end of the scale range to the minimum value in the current data set and the high end of the scale range to the highest value measured since the last reset.
- Zero - Max: Sets the low end of the scale to zero and the high end of the scale to the highest value measured since the last reset.

Reset Maximum Button

Click to reset the maximum value.



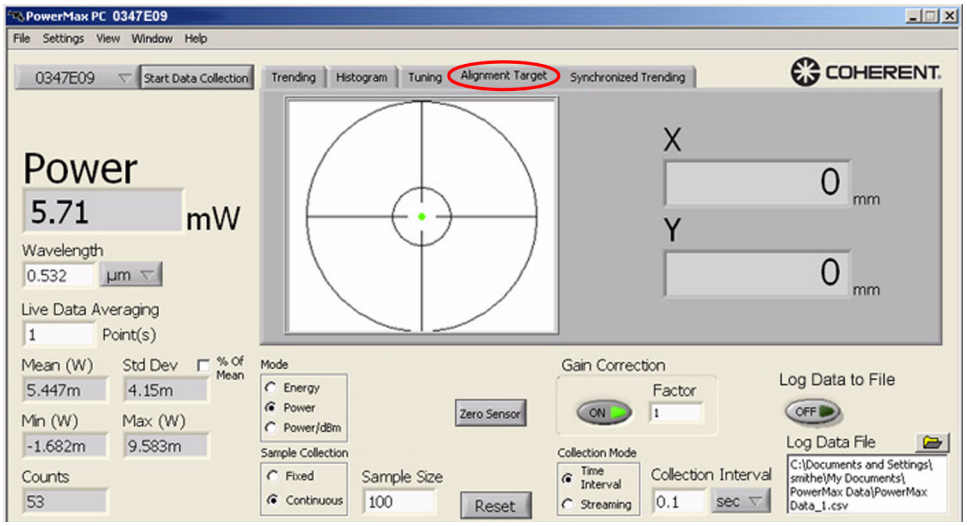
Alignment Target Chart

(*Position-sensing thermopile sensors only*)

The target represents the bull's-eye view of the laser beam position of the selected sensor. Position values are scaled and the outer ring refers to the aperture radius.

The dot on the target represents the position of the beam on the surface of the sensor. As the beam nears the edge of the aperture, the dot will display near the edge of the bull's-eye. This feature is useful when setting up the sensor for a measurement, especially with non-visible laser beams.

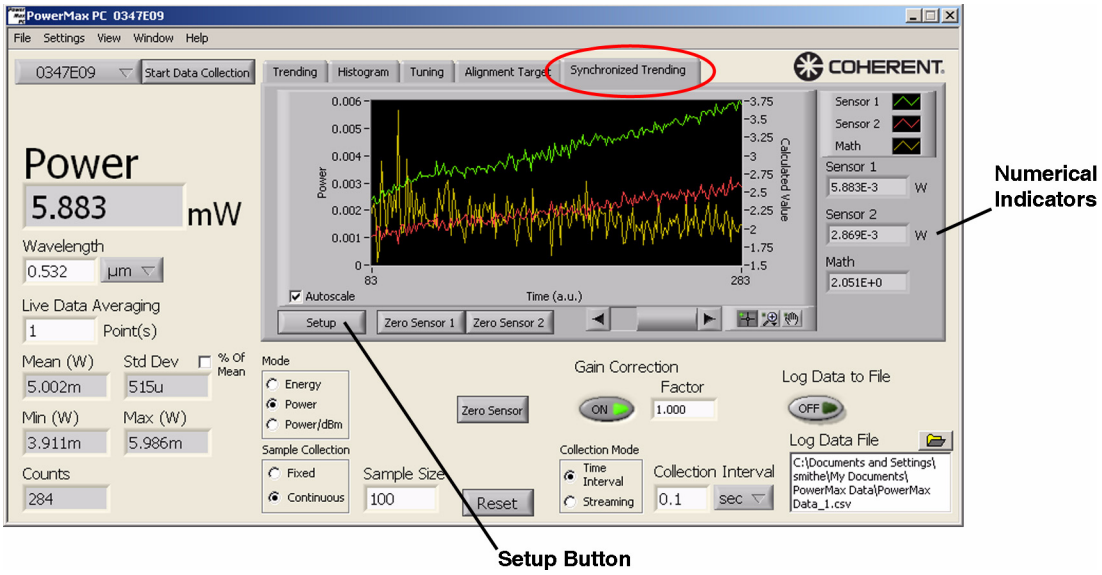
The Alignment Target tab only appears if a thermopile quad sensor is selected as the current data source.



Synchronized Trending Chart

When multiple sensors are available, this tab provides synchronized plotting of two sensors on the same chart. This screen also provides the option of performing math—such as ratiometry (A/B)—using two sensors.

The Synchronized Trending tab only appears if two PowerMax-USB sensors are available for control by the application. If you have two sensors connected—but two windows open—the Synchronized Trending tab will not be visible until you close one of the two windows.

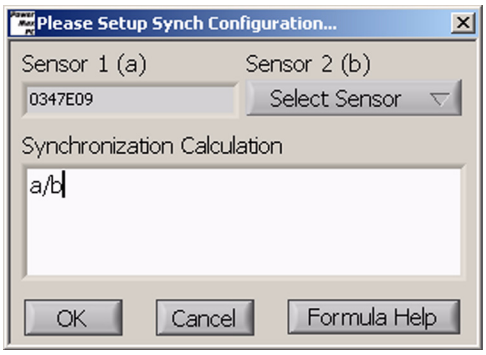


Numerical Indicators

These numerical indicators display the latest readout of both sensors (in Watts, Joules, or dBm, depending on measurement mode), as well as the optional synchronized calculated math value, if synchronized data collection is enabled.

Setup Button

Clicking the Setup button displays the following screen:



Options on this screen include:

- Selecting/deselecting the second sensor to be used for synchronized data collection
- Changing the *Synchronization Calculation* equation.

Sensor 1 (a)

Lists the serial number of the primary PowerMax sensor in use by the current Front panel.

Sensor 2 (b)

Lists all the connected PowerMax sensors that can be selected for synchronized trending use by the current Front panel.

- (*USB sensors*) The serial numbers of all available attached PowerMax-USB sensors are shown in the dropdown menu.
- (*RS sensors*) RS-232 COM port numbers will not appear in the dropdown menu because RS-232 sensors do not support synchronized data collection.

  Notes

  - After attaching a sensor, it may take several seconds for the serial number to appear on the list.
  - Sensors connected to your computer but already controlled by a Front panel will not appear in the Sensor 2 (b) dropdown list. If you de-select a sensor in a Front panel, the Sensor 2 (b) dropdown list automatically updates and that sensor will then be available for selection.

Synchronization Calculation

Lists the current formula used for math calculation on synchronized data. To change the formula, type the new formula into the *Synchronization Calculation* field—using the letter "a" to reference Sensor 1 and letter "b" to reference Sensor 2. An error dialog will appear if an invalid formula is entered.

Zero Sensor 1 Button

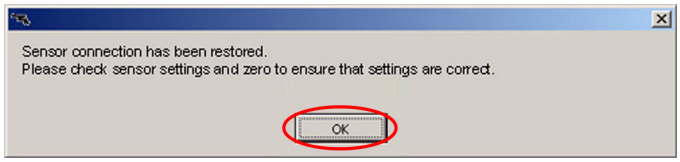
Click the Zero Sensor 1 button to zero the main sensor. Clicking on this button has the same effect as clicking on the main Zero Sensor button.

Zero Sensor 2 Button

Click the Zero Sensor 2 button to zero the second, synchronized sensor.

Reset Error

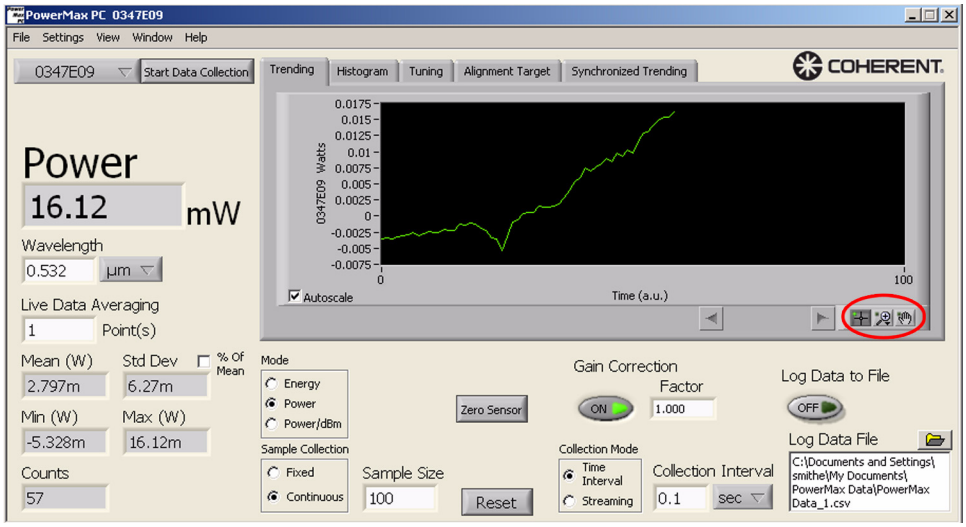
A separate error dialog window appears whenever a user action generates an error. This window will list the possible cause of the error, as well as other information. Here is an example:



You have to click the OK button in the error dialog window before new commands can be accepted.

Graph Palette

Allows you to zoom or move the plot displayed in the Trending chart.



Zoom Button

Click this button and then click an option button from the dropdown list to do any of the following actions:

- Drag the mouse to define the rectangular plot area that will be displayed in the chart.
- Drag the mouse to define the horizontal plot area that will be displayed in the chart.
- Drag the mouse to define the vertical plot area that will be displayed in the chart.
- Click this button to display all data points that have been collected.
- Click this button and then click anywhere on the chart to zoom in.
- Click this button and then click anywhere on the chart to zoom out.

Move Button

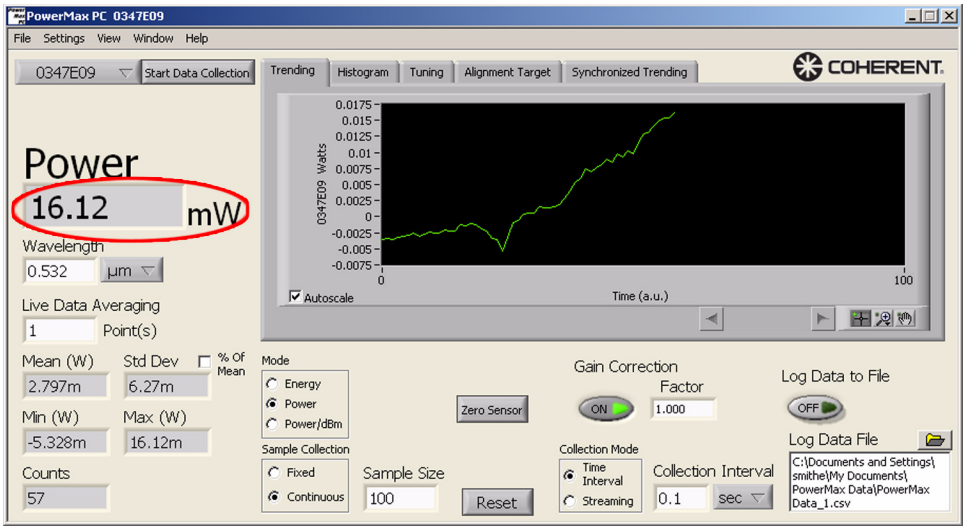
Click this button and then drag the mouse on the screen to move the plot in any direction.

(undefined) Button

This button is currently not used.

Live Reading

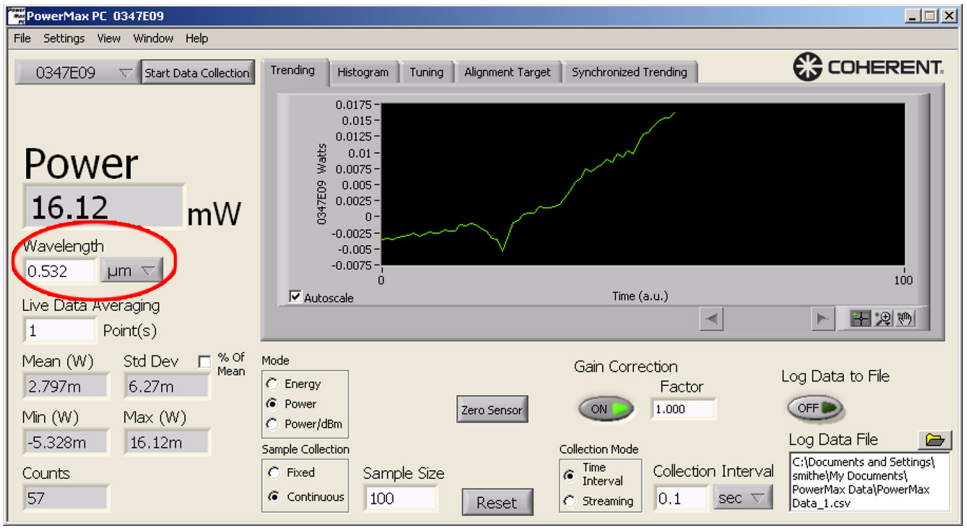
Displays the current sensor reading, if Live Data Averaging is set to 1 point. If Live Data Averaging is set to *n* points, the Reading indicator displays the average of the last *n* points.



Wavelength

The Wavelength field is used to configure the sensor to automatically account for spectral responsivity differences between the laser wavelength and the calibration wavelength. Use this field to enter your laser wavelength.

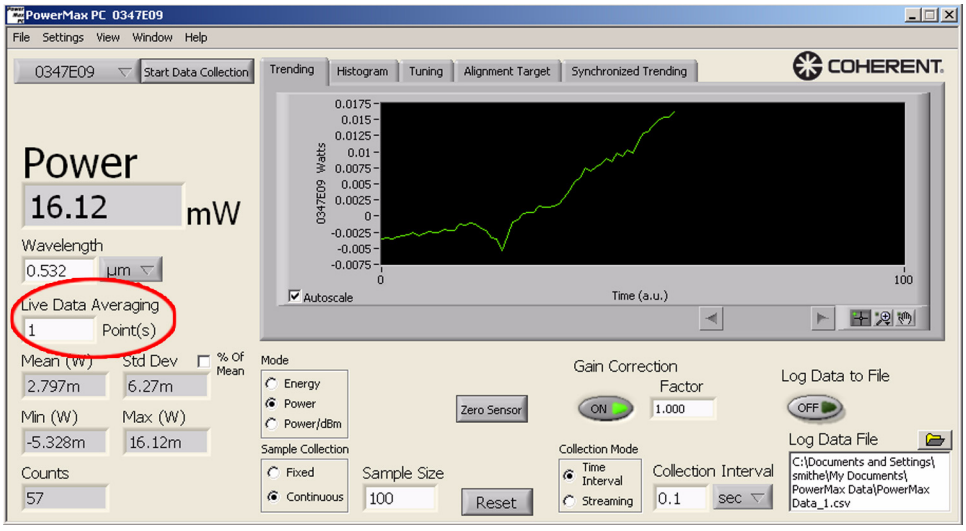
- *µm* is the unit default but can be changed to *nm* by clicking the units dropdown menu (next to the wavelength) and selecting *nm*.
- If a wavelength outside the allowable range is requested, the nearest minimum value or maximum value will be entered and displayed.



Live Data Averaging

Enables averaging of the last *n* data points for the power/energy and plot displays. This is computed as a moving average.

n can be set from 0-to-60 seconds and 2-to-1000 pulses, depending upon the mode of operation.

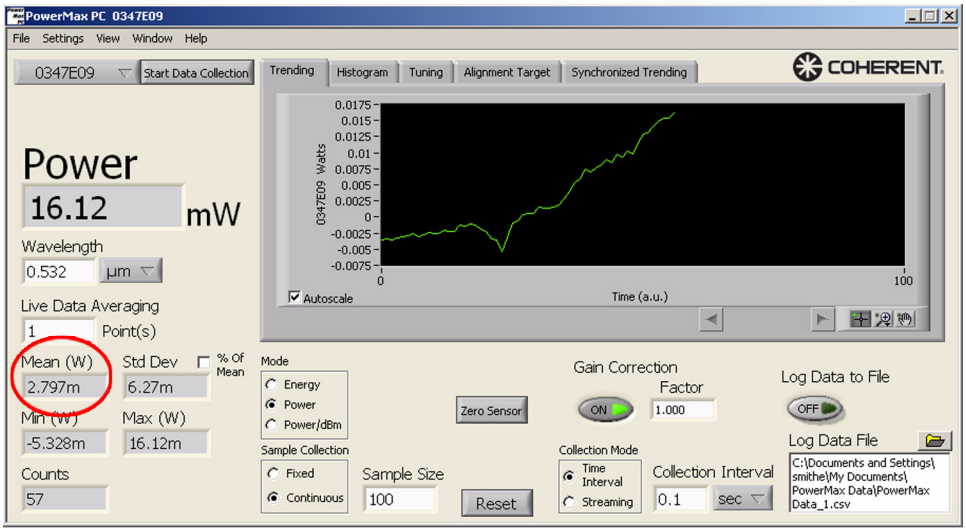


Notes:

- Live data averaging is always in points, with 10 points per second in Power mode, and arbitrary points per second in Pulsed Joules mode.
- With optical sensors, live data averaging is *always* in Power mode with 10 points per second.

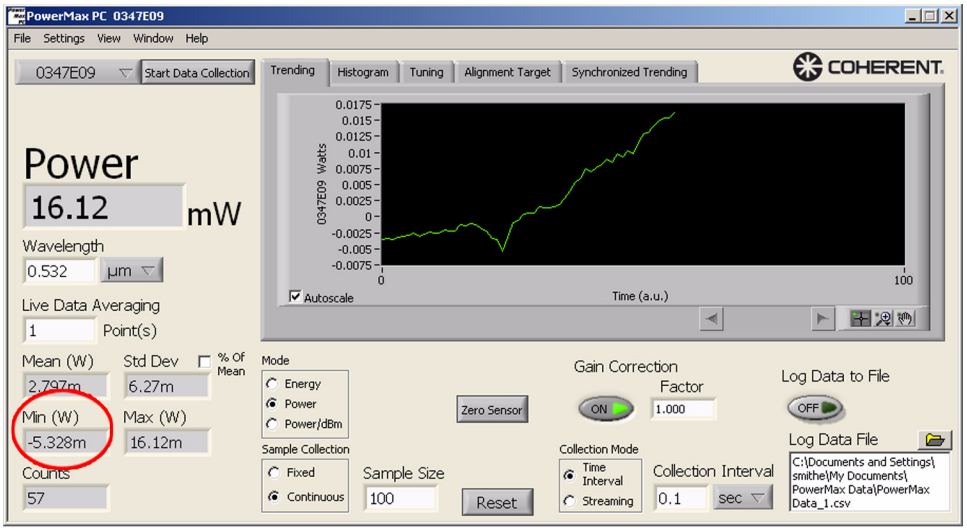
Mean

Displays the mean of the last *n* Sample Size samples. The value updates as new samples are acquired. A sample size of *100* will display the stats on two samples, then three, and continue to the n^{th} sample. If the software is in *Continuous* mode, the statistics will continue to update, using the last *n* samples. In *Fixed* mode, the statistics will hold after the n^{th} sample.



Min

Displays the minimum value in the last *n* Sample Size samples. The value updates as new samples are acquired. Example: A sample size of *100* will display the stats on two samples, then three samples, and continue to the n^{th} sample. If the software is in *Continuous* mode, the statistics will continue to update, using the last *n* samples. In *Fixed* mode, the statistics will hold after the n^{th} sample.

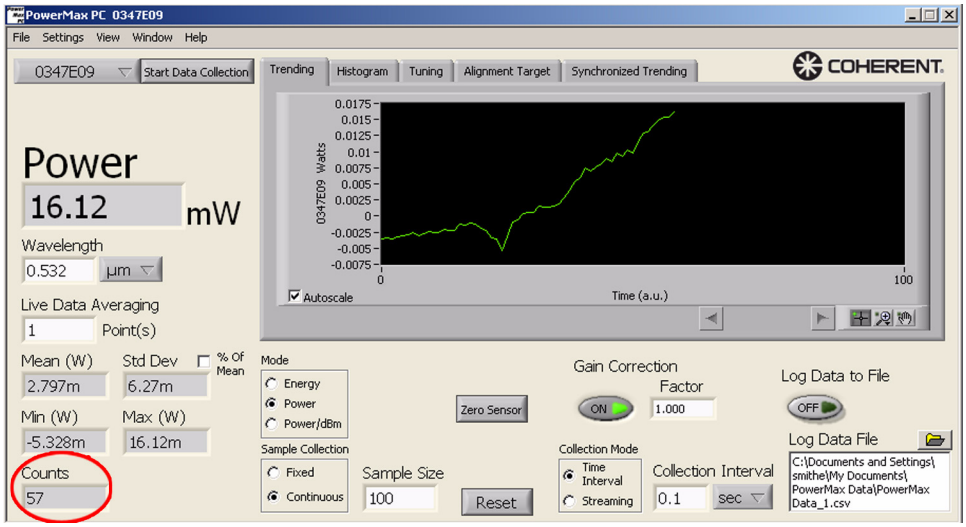


Counts

Displays the number of measurements taken in the current data set. Pressing the **Reset** button resets the counter.

- In *Fixed Sample Collection* mode, the *Counts* field increments until the batch contains the number of samples entered in the Sample Size field. At this point, the statistics and the Trending chart will stop updating.
- In *Continuous Sample Collection* mode, the *Counts* field continues incrementing indefinitely as more samples are collected in the batch and plotted in the Trending chart. Even though the *Counts* field continues to increment, the statistics parameters themselves are calculated from the last *n* number of samples, and the Trending chart displays the last *n* number of

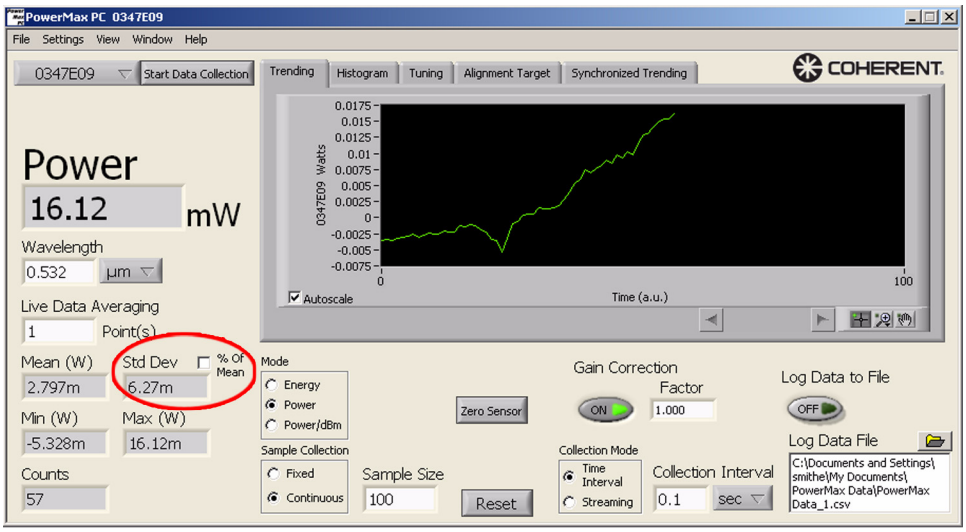
samples, where *n* is the number of samples entered in the Sample Size field.



Std Dev

Displays the Standard Deviation of the last *n* Sample Size samples. The value updates as new samples are acquired. Example: A sample size of *100* will display the stats on two samples, then three samples, and continue to the n^{th} sample.

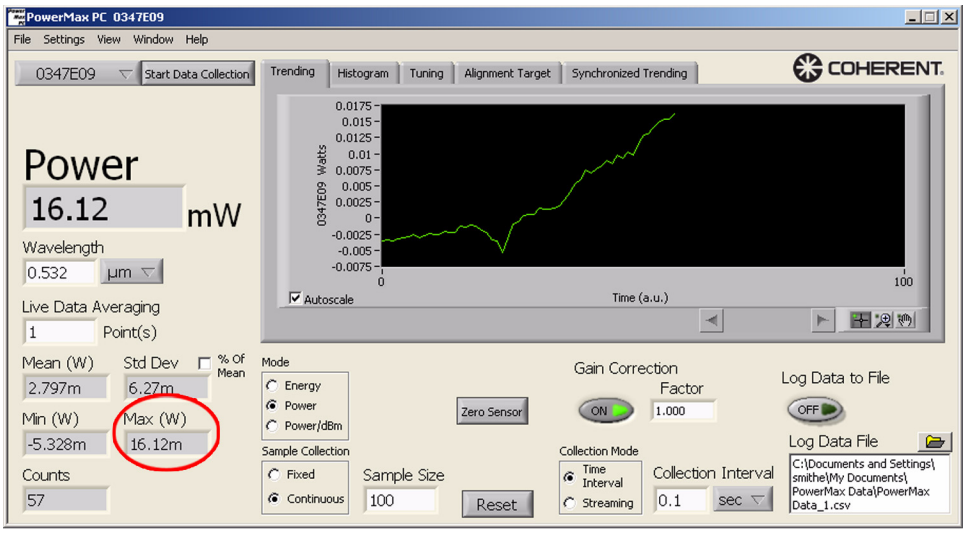
- If the software is in *Continuous* mode, the statistics will continue to update, using the last *n* samples.
- In *Fixed* mode, the statistics will hold after the n^{th} sample.



Max

Displays the maximum value in the last *n* Sample Size samples. The value updates as new samples are acquired. Example: A sample size of *100* will display the stats on two samples, then three samples, and continue to the n^{th} sample.

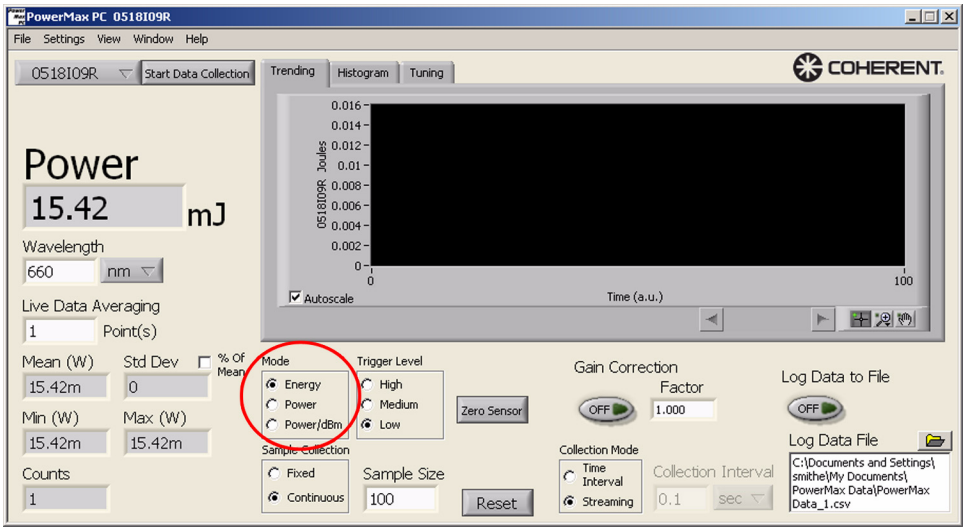
- If the software is in *Continuous* mode, the statistics will continue to update, using the last *n* samples.
- In *Fixed* mode, the statistics will hold after the n^{th} sample.



Mode

Selects the measurement mode: Energy (J), Power (W), or Power/dBm.

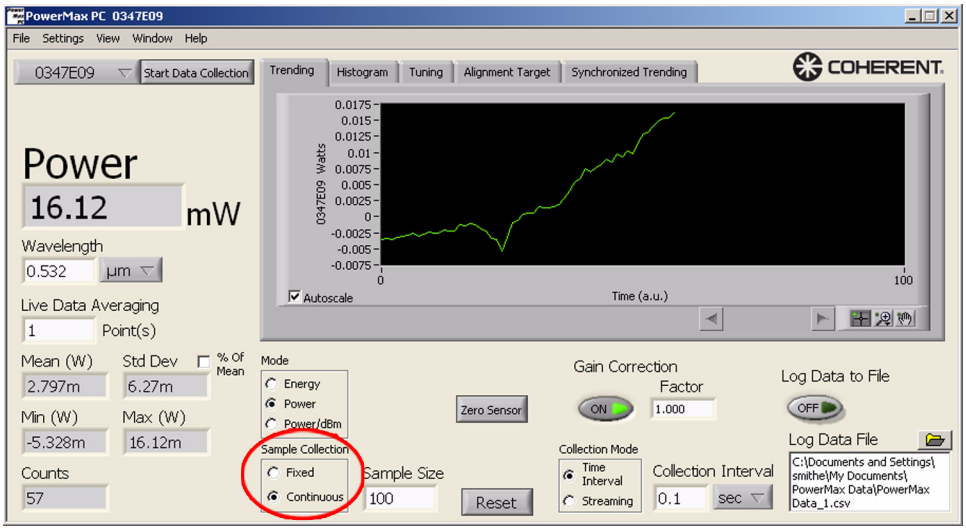
Energy refers to a special *"*long-pulse joules*"* mode using a thermopile sensor in which the energy in a single long-pulse greater than 1 msec can be integrated by the thermopile sensor to calculate and display the energy in the pulse.



Sample Collection

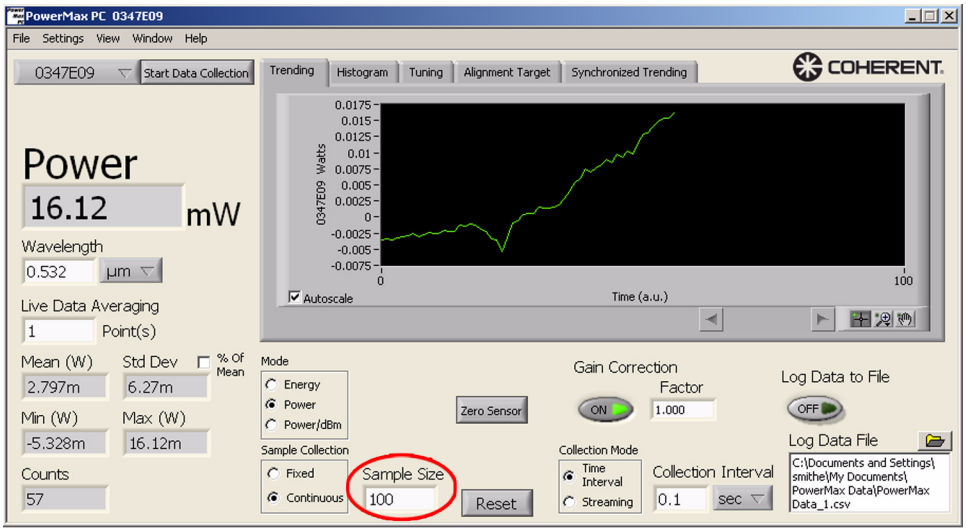
Selects the logging/plotting mode:

- *Fixed* takes and plots the number of data points shown in the Sample Size and holds the results after the n^{th} sample.
- *Continuous* takes continuous data and plots the number of data points shown in the Sample Size in the chart window. The newest data continually scrolls in the window.
- The default sample rate for all PowerMax-USB and PowerMax-RS sensors is 10 samples per second. To use a different sample rate, change the Collection Interval.

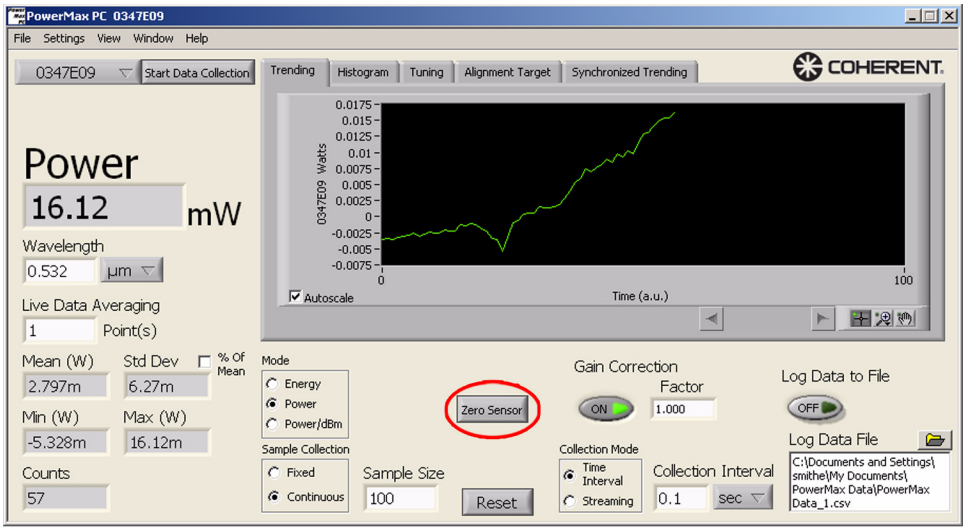


Sample Size

Selects the sample size to collect when in *Fixed* mode, and the sample size to use for statistics when in either *Fixed* or *Continuous* mode.

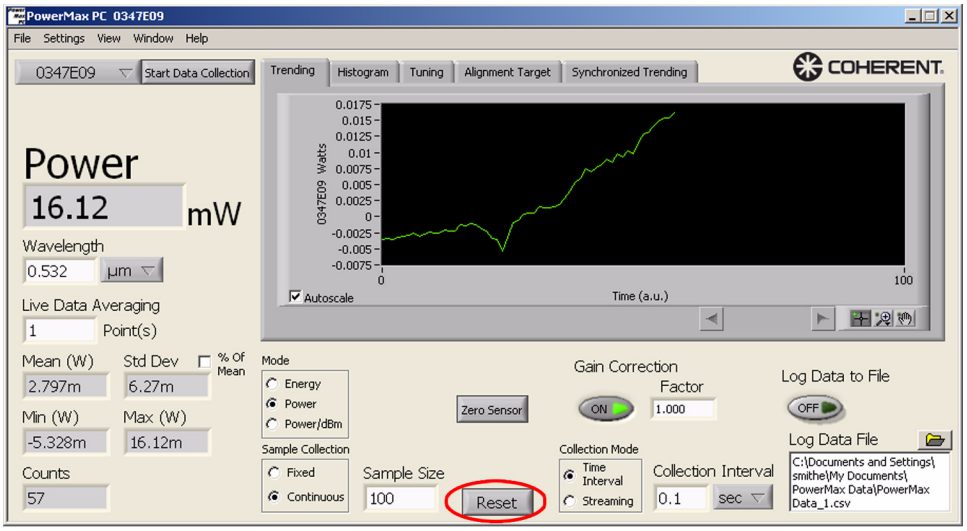


Zero Sensor Zeroes the PowerMax sensor.



Reset Button Clicking the **Reset** button:

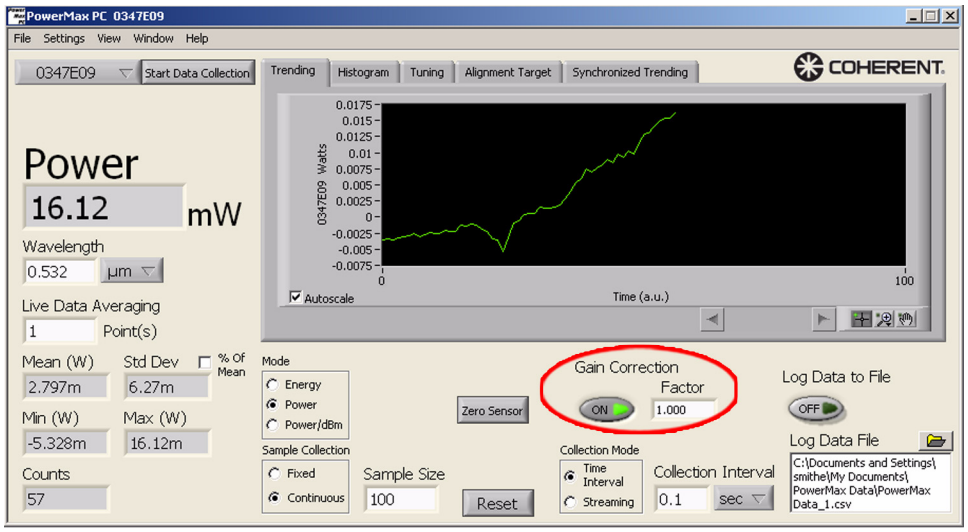
- Resets the data set used for statistics (Mean, Min, Max, and Std Dev).
- Resets Counts to 1.
- Clears Trending and other charts.



Gain Correction

Enables/disables Gain Correction.

- Default value: Off
- Range: On (True), Off (False)
- When Gain Correction is enabled, measurements taken by the sensor will be multiplied by the Gain Factor.



Gain Correction Factor

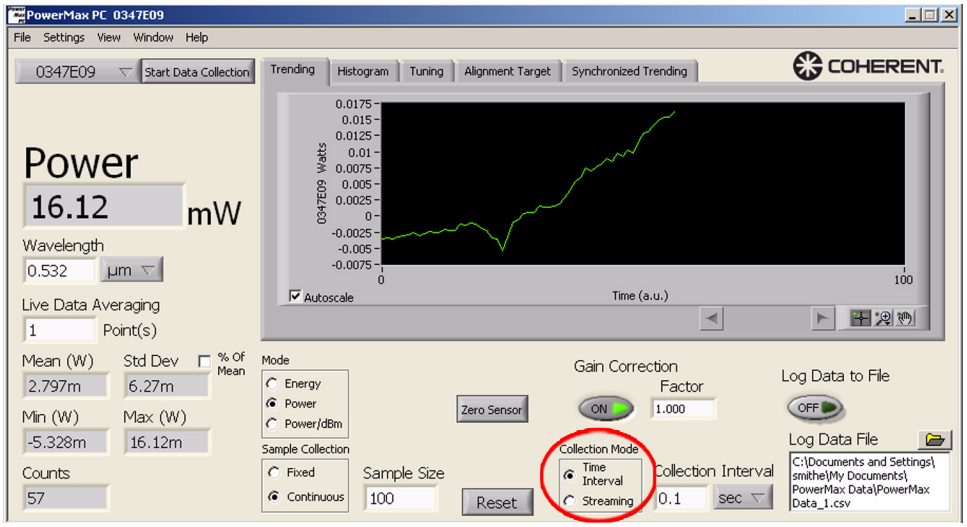
Sets the gain correction factor stored in the PowerMax sensor.

- Default Value: 1.0
- Range: 0.001 to 100000.0

The Gain Correction Factor control indicates the current gain correction factor stored in the PowerMax sensor. To change this setting, enter the desired factor into the Gain Correction Factor control. This factor is not applied unless Gain Correction is enabled.

Collection Mode

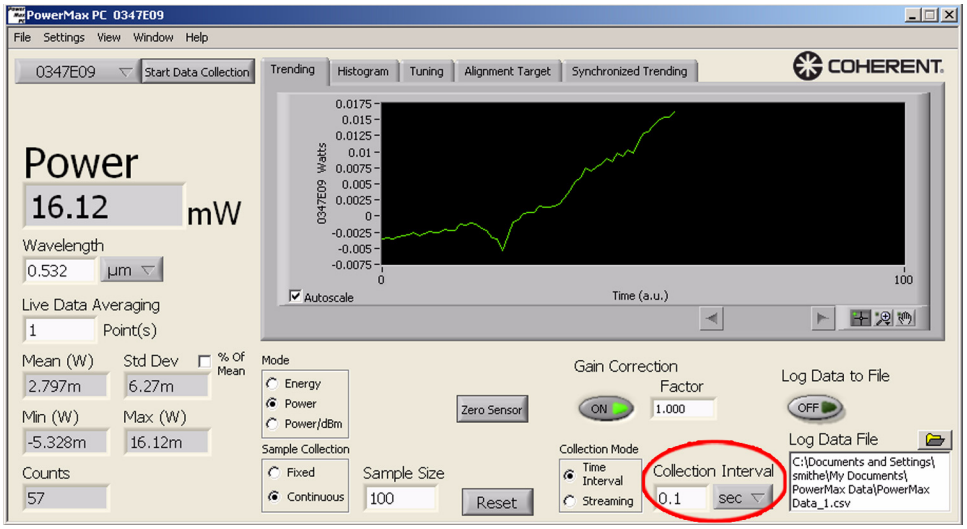
Selects between continuous data acquisition and data acquisition on a fixed-time interval.



Changing between *Time Interval* and *Streaming* collection modes during data collection automatically clears the data plot display and the statistics batch. Clearing the plot display and statistics batch is done to prevent mixing of data sets with two different time bases. When set to *Streaming*, the collection interval is automatically set to 0.1 seconds.

Collection Interval

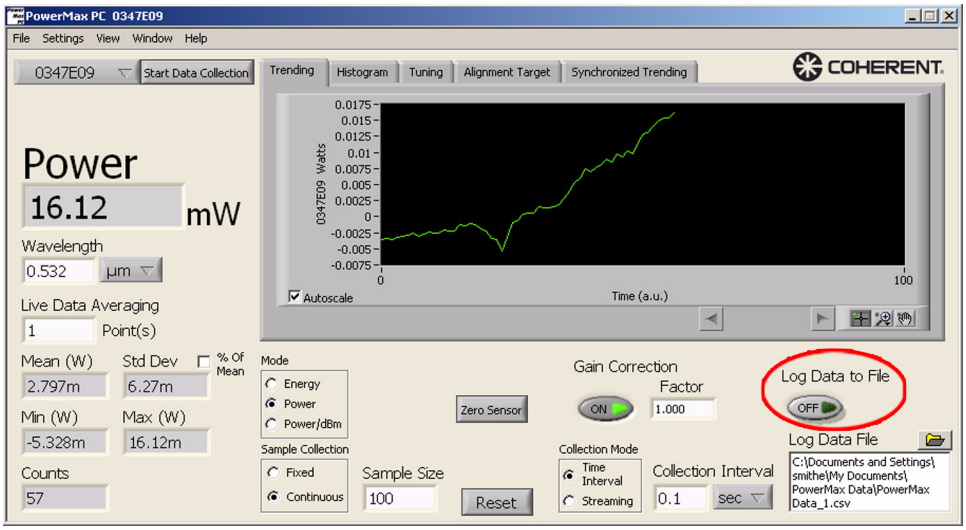
Sets the collection interval (seconds, minutes, or hours) when Collection Mode is set to *Time Interval*. This control is grayed-out when Collection Mode is set to *Streaming*.



Log Data to File

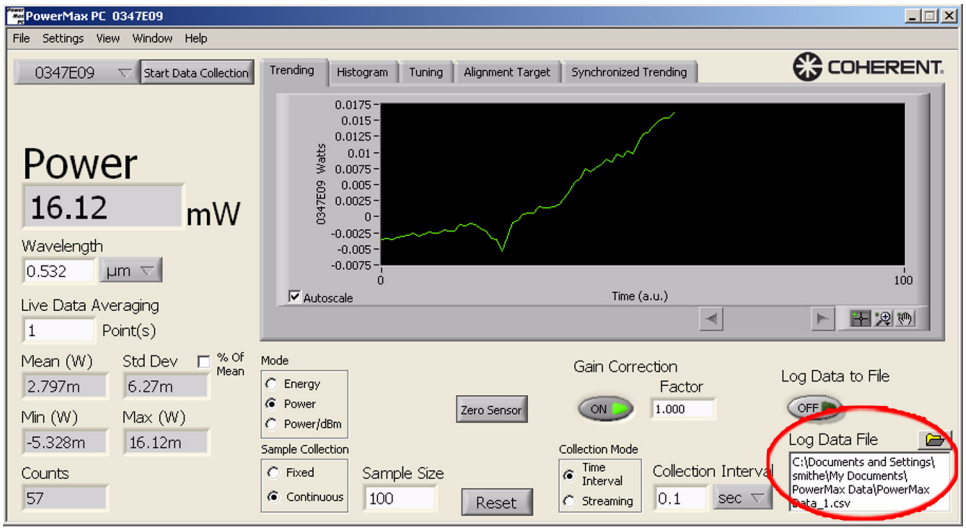
Enables/disables saving currently-acquired data to the Log Data file:

- If the Collection mode is *Time Interval*, data is logged to the Log Data file at the interval specified under Collection Interval.
- If the Collection mode is *Streaming*, all data is logged to the Log Data file.



Log Data File

Lists the file currently used to log data. The file is saved in "csv" (Comma-Separated Values) format, which you can automatically open in Excel by double-clicking on the file name. To view a previously-saved data file, select View Saved Data File from the File menu.



Each time you toggle the Log Data to File button, the number appended to the file name is automatically incremented - this prevents the accidental overwriting of data.

Menus

Five drop-down menus appear on the PowerMax PC Front panel: File, Settings, View, Window, and Help. This section discusses each of those menus.

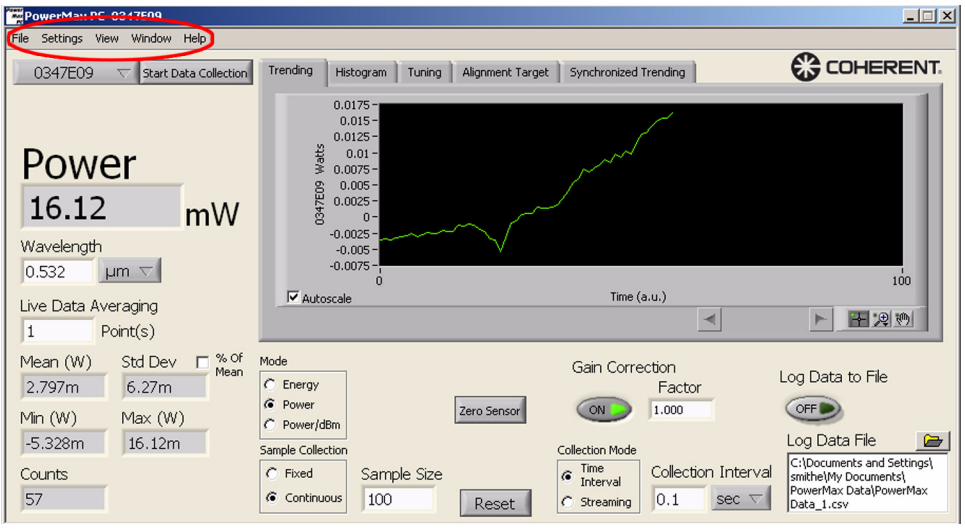


Figure 6. Drop-Down Menus

File Menu

Options available under the File menu:

- Viewing a previously-saved data file (*shortcut: <Ctrl>+<V>*) (page 41)
- Opening a new Front panel (*shortcut: <Ctrl>+<N>*) (page 42)
- Printing the current window (*shortcut: <Ctrl>+<P>*) (page 43)
- Printing the current graph or chart (page 44)
- Exiting the program (*shortcut: <Ctrl>+<Q>*) (page 44)

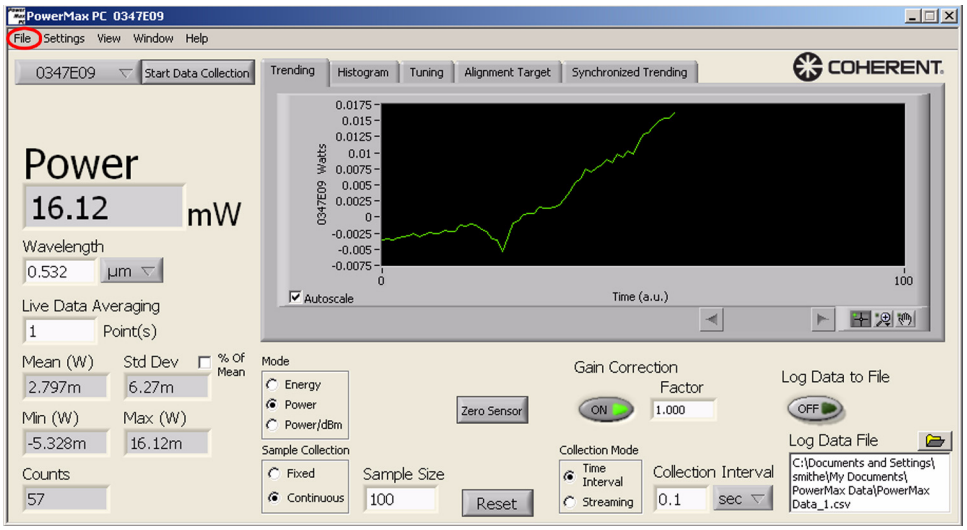
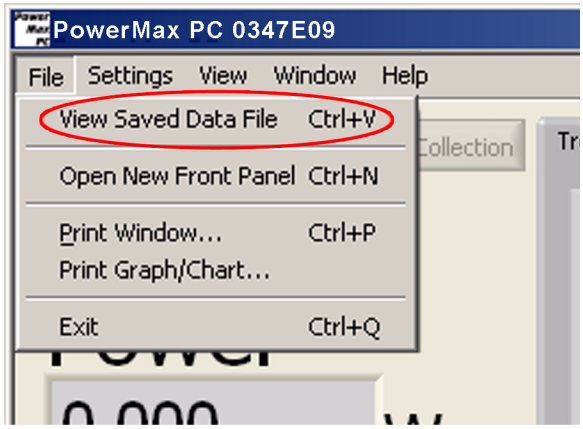


Figure 7. File Menu

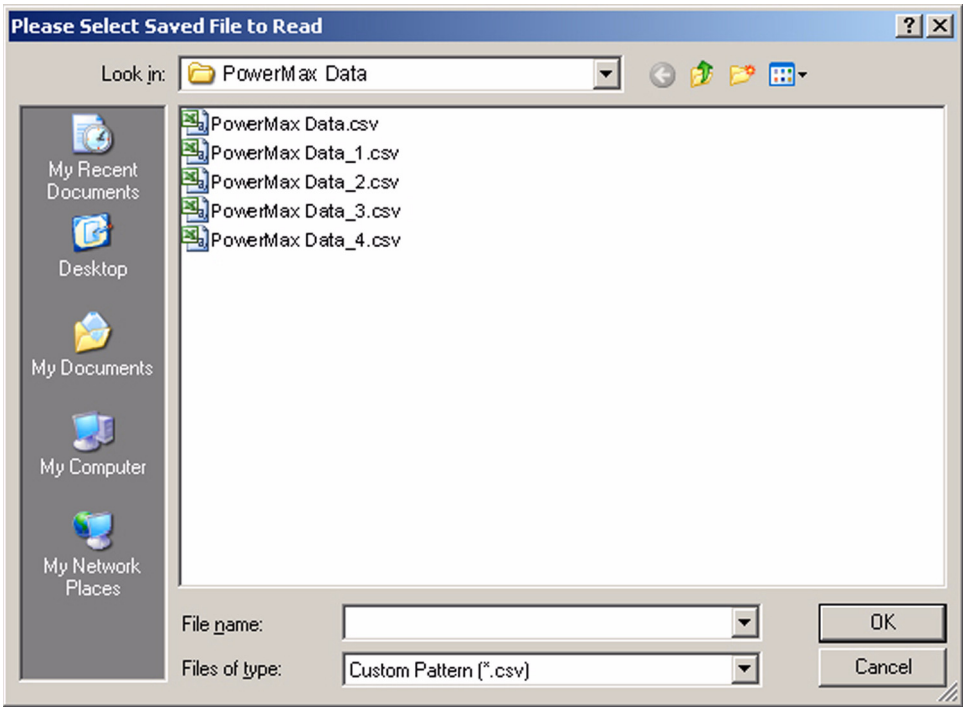
View Saved Data File

To view information previously saved in a data file:

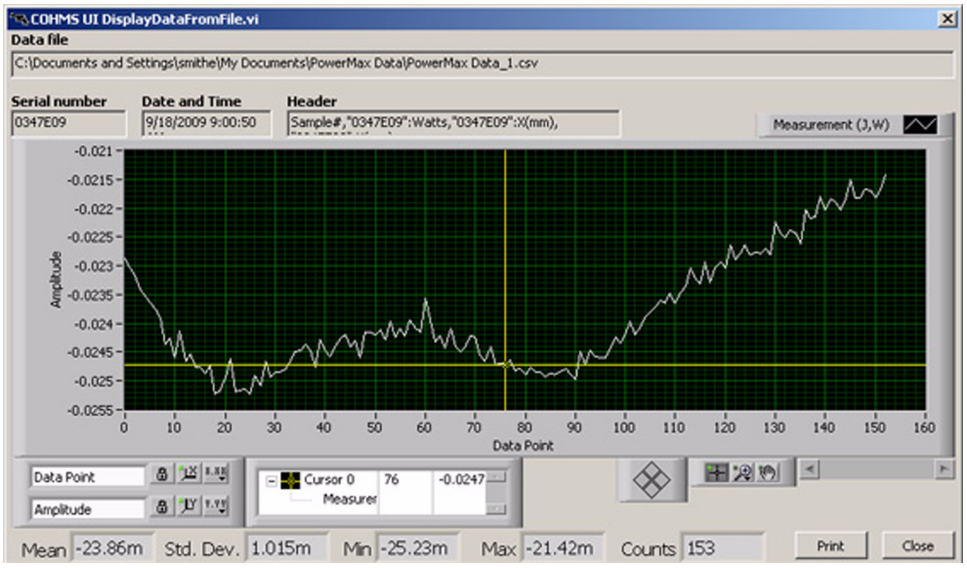
1. Click *View Saved Data File* (*shortcut: <Ctrl>+<V>*) from the File dropdown menu:



A menu similar to the following will display:



2. Select the name of the file you want to view and then click **OK** to display a chart that contains all the saved data. Here is an example chart:

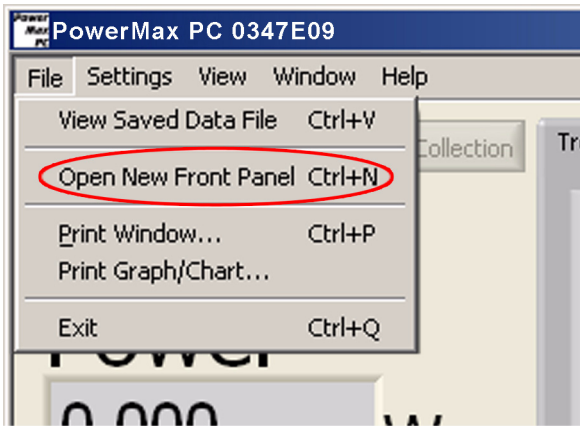


Open New Front Panel

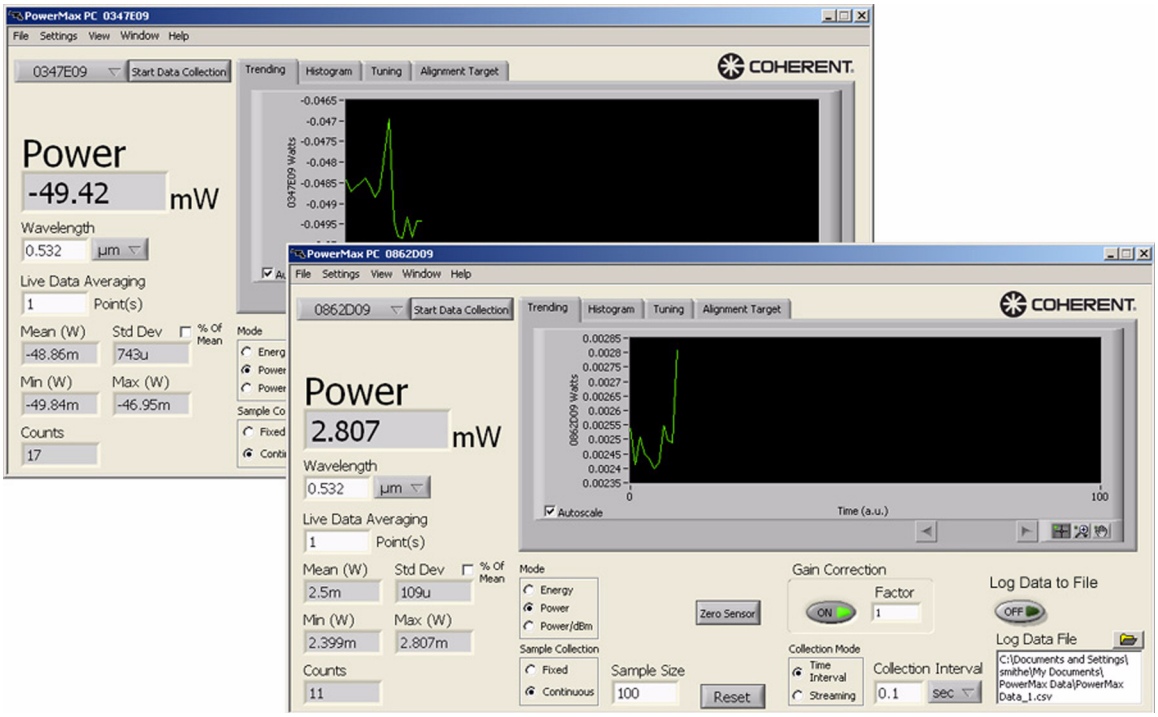
The purpose of opening a new Front panel is to control, monitor, and simultaneously log data—from multiple sensors—to separate files. This is useful for burn-in stations, where it is necessary to collect data from several lasers at the same time by running several PowerMax sensors on one PC.

A sensor cannot be active in more than one Front panel at a time.

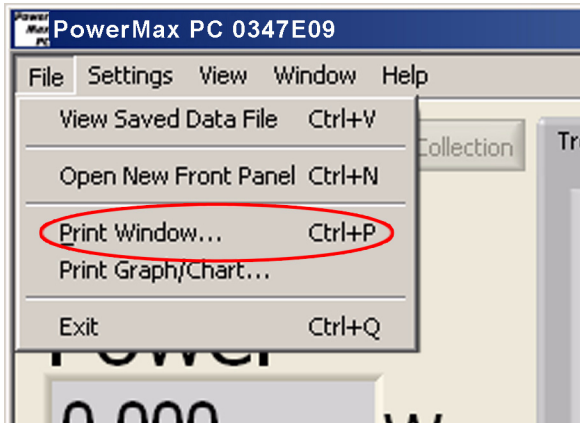
To open a new panel, click *Open New Front Panel* (shortcut: <*Ctrl*>+<*N*>) from the File dropdown menu:



Here is an example of data from two sensors, each displayed within its own Front panel:

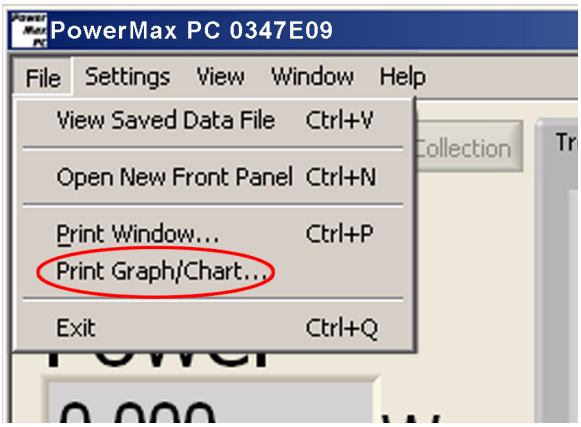


Print Window



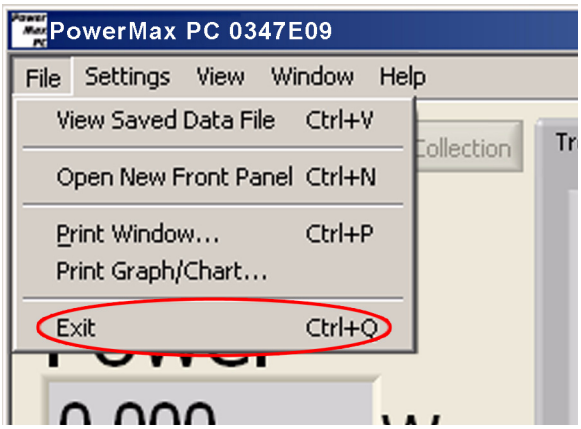
Selecting *Print Window* (shortcut: <*Ctrl*>+<*P*>) from the File drop-down menu prints the entire active window—including graphs and charts—exactly as it appears on the screen.

Print Graph/Chart



Like the Print Window option, selecting *Print Graph/Chart* on the File dropdown menu prints the entire active window; however, this option uses *inverted* colors to print graphs and charts.

Exit



Selecting the *Exit* option (shortcut: <*Ctrl*>+<*Q*>) on the File drop-down menu closes the PowerMax PC program.

Settings Menu

Options available under the Settings menu:

- Turning Speedup on or off (page 45)
- Choosing the log file format (refer to "Log Data File" on page 39 and "Log Data to File" on page 39 for general information about saving data)
- Showing RS-232 ports (page 46)

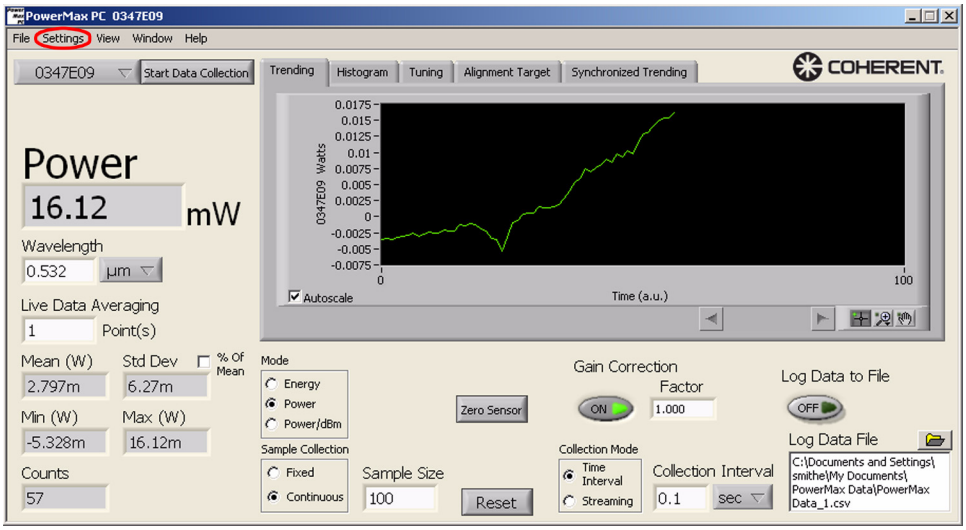
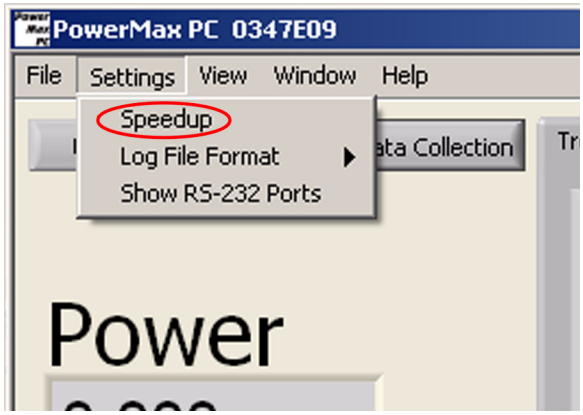


Figure 8. Settings Menu

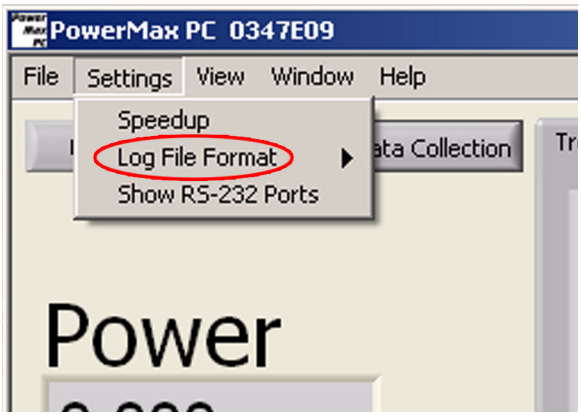
Speedup



Selecting or de-selecting *Speedup* on the Settings dropdown menu controls the host data.

Due to the natural thermal response of thermopile sensors, they have a relatively slow response speed. To make faster measurements with these sensors, use a speedup algorithm while taking power measurements. The *Speedup* option allows you to turn this algorithm on or off for various functions. The trade off to using *Speedup* is some loss of accuracy.

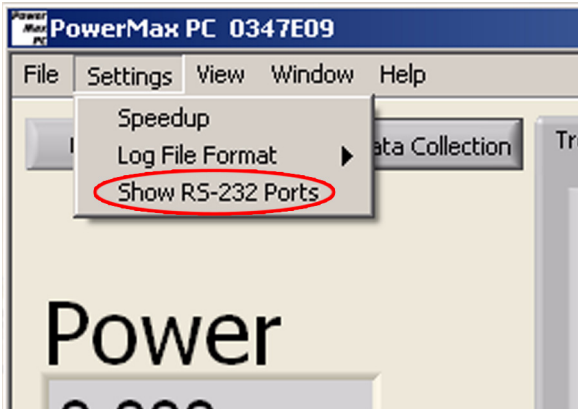
Log File Format



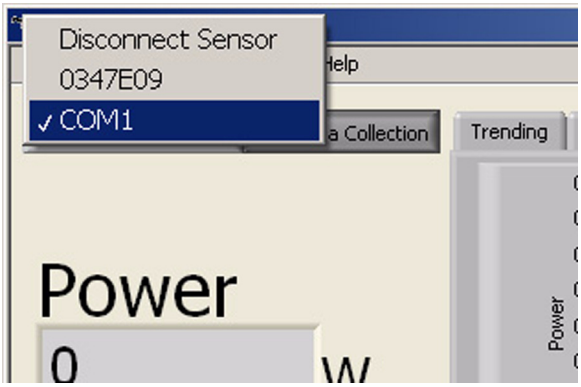
Selecting *Log File Format* from the Settings dropdown menu allows the following options to be added or removed from the log file:

- Sensor data
- Calculated (ratio) data
- Position-Sensing Thermopiles: X Position, Y Position
- (*thermopile quad sensors only*) X and Y positions

Show RS-232 Ports



Enabling this option will list available RS-232 ports on the Select Sensor dropdown list. To select the RS-232 port, click on the appropriate COM number in the dropdown list. Here is an example:



View Menu

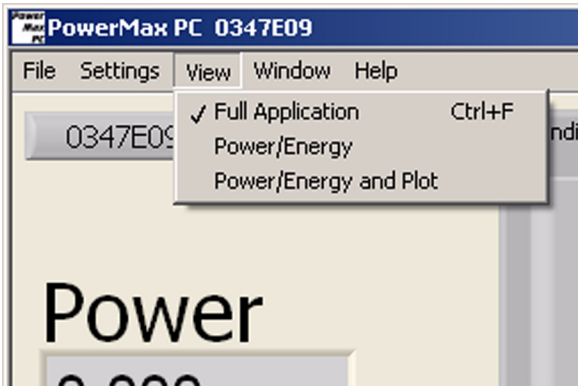
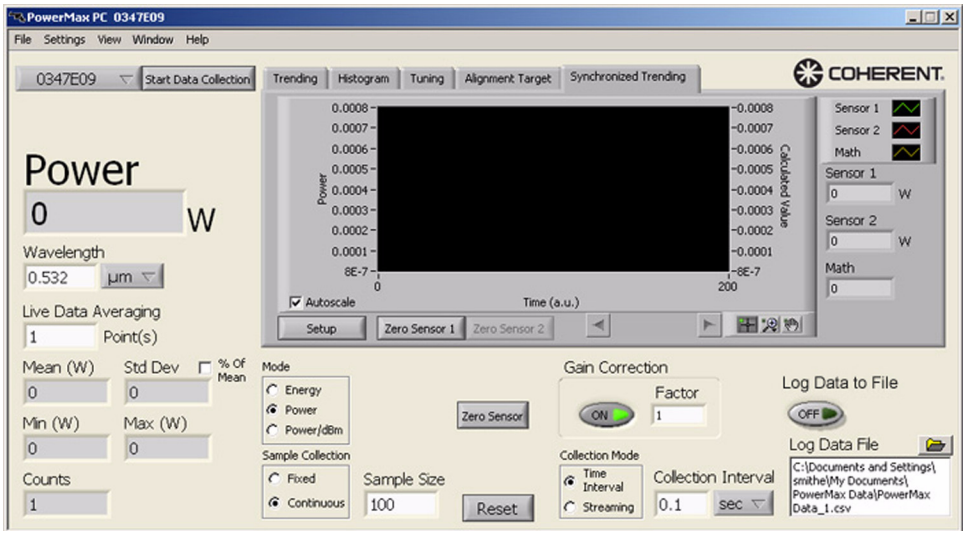


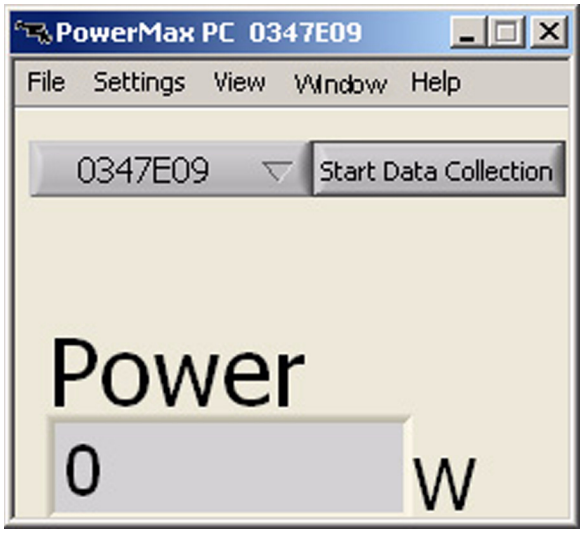
Figure 9. View Menu

Use this menu to select which portion of the display is visible: *Full Application*, *Power/Energy*, or *Power/Energy and Plot*.

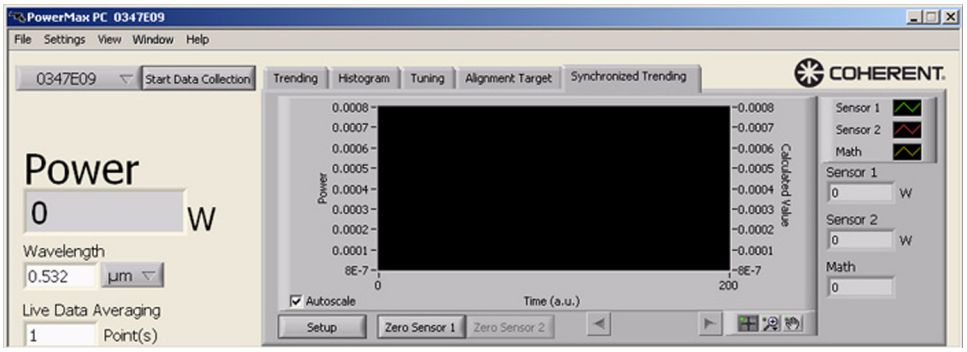
- Example of a *Full Application* (*shortcut: <Ctrl>+<F>*) view:



- Example of a *Power/Energy* data view:



- Example of a *Power/Energy and Plot* view:



Window Menu

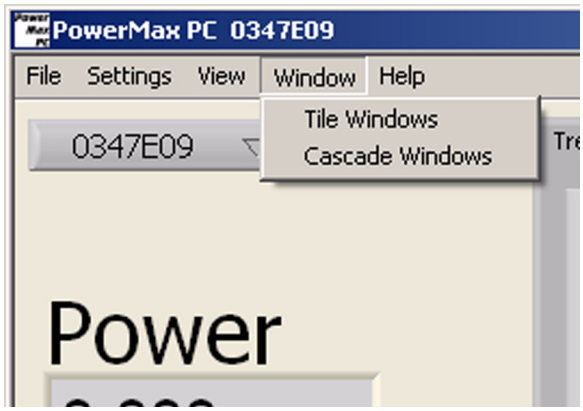


Figure 10. Window Menu

When more than one window is open—that is, when there is more than one sensor connected to the computer and each sensor has its own Front panel open—this menu item allows you to determine the relative position of the open Front panels on the monitor screen. Options available under the Window menu are:

- *Tile Windows*: Displays open Front panels edge-to-edge.

If five or more Front panels are open, only the first four panels will tile—the rest of the open panels will stay in their current location.

- *Cascade Windows*: Displays all open Front panels, stacked and cascading from the upper left to the lower right of the screen.

Help Menu

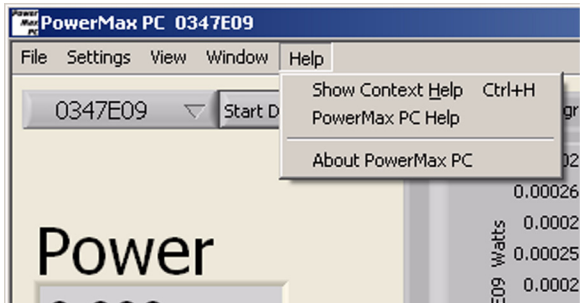
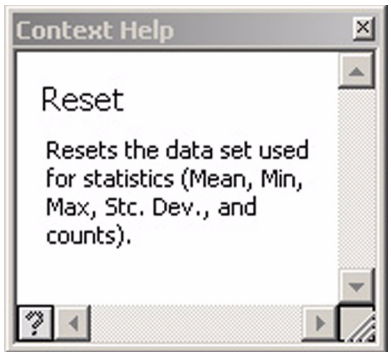


Figure 11. Help Menu

Options available under the Help menu:

- *Show Context Help*: Opens a separate window that displays information about the screen item currently beneath the mouse cursor (*shortcut: <Ctrl>+<H>*). For example, a screen similar to the following will appear if you select *Show Context Help* and then hover the cursor over the **Reset** button:



  To turn this feature off, either de-select it from the Help drop-down menu, or click the "X" in the top right-hand corner of the Context Help screen.

- *PowerMax PC Help*: Displays this Help file
- *About PowerMax PC*: Displays version and copyright information for the PowerMax PC software. For example:

HOST INTERFACE

In this section:

- Introduction (this page)
- Message terminators (page 52)
- Host command quick reference (page 53)
- SCPI interface section (page 55)
- Legacy LaserPAD/SSIM interface section (page 65)
- Data streaming transmission interface section (page 70)
- Operational parameters (page 71)

Introduction

For those customers who want to communicate with Coherent PowerMax-USB and PowerMax-RS sensors over a host interface—instead of using our PowerMax PC software—we are providing a complete remote host command interface that can be used to control all aspects of sensor operation. You can use this host interface environment to communicate with these sensors in an ad hoc manner using a terminal emulator, or to write custom software in a number of programming environments, including Visual Studio and LabVIEW.

The PowerMax-USB sensors utilize a standard Windows COM class driver and operate much like a serial port. After the driver is installed, the sensor will show up as a device on the computer's COM port and the host interface will accept commands and respond in ASCII format using commands that adhere to the SCPI standard.

The sensors also support a second ASCII command set used by our legacy LaserPAD/SSIM products, which allow drop-in software compatibility. For new software installations, we recommend using the newer SCPI-based command set.

For customers who prefer to capture streaming data over the host port—instead of the query method—we have implemented a special data streaming command interface. This interface requires the user to monitor for a high/low bit (as described under “Data Streaming Transmission Interface Section” on page 70), and is a more advanced interface than the standard SCPI ASCII command language. For customers who want streaming, and who want to

stream in a purely ASCII format, there is a command in the legacy LaserPAD/SSIM command set that can be used (refer to "Legacy LaserPAD/SSIM Interface Section" on page 65).

The PowerMax-RS sensors support the same command set as the PowerMax-USB sensors. No driver is required, as they function as a serial device on an RS-232 port.

For customers who prefer to program in the National Instruments LabVIEW environment, we provide a full set of LabVIEW drivers on the installation CD that shipped with your system. In addition to a basic Getting Started VI that will show you how to initiate communication with a PowerMax-USB or PowerMax-RS sensor, we also provide access to the architecture of our PowerMax PC software, which was written using our LabVIEW driver library.

Message Terminators

Messages between the sensor and the host computer are comprised entirely of ASCII string characters, and all message strings passing through the host interface are terminated to signal the end of a message string.

The one exception to messages comprised entirely of ASCII string characters is the Data Streaming Transmission Interface. After data streaming is initiated, the host sends unsolicited streaming data in non-ASCII format in which a high bit is set on all transmissions. The streaming data mode is covered under "Start Data Streaming Command" and "Stop Data Streaming Command," beginning on page 68.

Messages Received by the Sensor

Messages received by the sensor must be terminated by a carriage return (decimal 13). Line feed characters (decimal 10) are discarded so message terminator flexibility can be attained. A command or query is considered incomplete without the terminator. The maximum length of any message received by the sensor is 200 bytes.

Messages Sent by the Sensor

All legacy SSIM messages sent by the sensor (defined under "Legacy LaserPAD/SSIM Interface Section" on page 65) are terminated by a carriage return.

All other messages sent by the sensor (defined under "SCPI Interface Section" on page 55 and "Data Streaming Transmission Interface Section" on page 70) are terminated by a carriage return and line feed pair.

Host Command Quick Reference

The following table gives a brief description of all host commands. For detailed information about a specific command, go to the page referenced in the right-hand column.

Table 5. Host Command Quick Reference (Sheet 1 of 2)

Command	Description	Page #
SCPI INTERFACE		
SCPI Common Commands		
*RST	Resets all operational parameters to their power-on states.	56
*IDN?	Queries the sensor identification string.	56
System Options		
SYSTem:STATus?	Queries the system status.	56
SYSTem:INFormation:TEMPerature?	Queries the sensor temperature.	57
SYSTem:SYNC	Resets the system measurement sync timer.	57
SYSTem:SYNC?	Queries the system measurement sync timer.	57
SYSTem:COMMunicate:HANDshaking	Selects the state of SCPI message round trip handshaking.	57
SYSTem:COMMunicate:HANDshaking?	Queries the state of SCPI message round trip handshaking.	57
Error Record Reporting and Collection		
SYSTem:ERRor:COUNt?	Queries the number of error records in the error queue at the time of the query.	59
SYSTem:ERRor:NEXT?	Queries the next error record(s) in the error queue.	59
SYSTem:ERRor:ALL?	Queries all error records in the error queue at the time of the query.	59
SYSTem:ERRor:CLEar	Clears all error records in the error queue.	60
Measurement Setup and Control		
CONFigure:MEASure	Sets the sensor measurement mode.	60
CONFigure:MEASure?	Queries the sensor measurement mode.	60
CONFigure:SPEedup	Sets the speedup state.	60
CONFigure:SPEedup?	Queries the speedup state.	60
CONFigure:WAVElength	Sets the current wavelength.	60
CONFigure:WAVElength?	Queries the current wavelength.	60
CONFigure:GAIN:COMPensation	Enables or disables gain compensation.	61
CONFigure:GAIN:COMPensation?	Queries the state of gain compensation.	61
CONFigure:GAIN:FACTor	Sets the gain compensation factor.	61
CONFigure:GAIN:FACTor?	Queries the gain compensation factor.	61
CONFigure:ZERO	Sets the current measurement as the zero baseline measurement.	61
TRIGger:PTJ:LEVel	Selects the pulsed thermopile Joules mode trigger sensitivity level.	62
TRIGger:PTJ:LEVel?	Queries the pulsed thermopile Joules mode trigger sensitivity level.	62
Measurement Reading		
READ?	Queries the last recorded measurement at the time of the query.	62
Sensor Information		

Table 5. Host Command Quick Reference (Sheet 2 of 2)

SYSTem:INFormation:SNUMber?	Queries the serial number.	63
SYSTem:INFormation:CDATe?	Queries the calibration date.	63
SYSTem:INFormation:MDATe?	Queries the manufacturing date.	63
SYSTem:INFormation:TYPE?	Queries the sensor type and connection configuration.	64
SYSTem:INFormation:DIAMeter?	Queries the aperture diameter.	64
SYSTem:INFormation:WAVElength?	Queries the default wavelength.	64
LEGACY LASERPAD/SSIM INTERFACE		
h	Queries the list of LaserPAD/SSIM commands.	65
*rst	Resets all operational parameters to their power-on states.	65
*ind	Queries the hardware description.	66
v?	Queries the firmware version.	66
vp?	Queries the data stream protocol version.	66
msn?	Queries the serial number.	66
mcal?	Queries the calibration date.	66
mfg	Queries the manufacturing date.	66
df?	Queries the sensor family.	66
app	Queries the aperture diameter.	67
rmi	Queries the minimum range.	67
rmx	Queries the maximum range.	67
spd?	Queries the speedup state.	67
spd	Toggles the speedup state.	67
wl?	Queries the default wavelength.	67
wv?	Queries the current wavelength.	67
wv	Sets the current wavelength.	68
pw?	Queries the current power reading.	68
pos	Queries the current beam position.	68
tmp	Queries the current thermistor ADC value.	68
dst	Enables LaserPAD/SSIM interface data streaming.	68
dsp	Disables LaserPAD/SSIM interface data streaming.	69
DATA STREAMING TRANSMISSION INTERFACE		
INITiate	Enables data streaming interface transmission.	70
ABORt	Disables data streaming interface transmission.	70

SCPI Interface Section

Syntax and Notation Conventions

Unless otherwise specified, all SCPI commands and queries follow the syntax and notation conventions specified by the SCPI Standard. For more information, refer to the SCPI Standard—found on the IVI Foundation website.

The base-10 numeric data format specification is used heavily in this document. Unless otherwise specified, numeric data items are represented as:

- integer values
- non-scientific notation floating point values
- scientific notation floating point values (upper or lower case E)

For example, the following data values are functionally equivalent:

- 31256
- 31256.0
- 3.1256E4
- 31.256E3
- +3.1256E+4.

Unless otherwise specified, non-numeric data items (typically referred to as strings) are not quoted.

Enumerated values must exactly match, using the long form/short form comparison rules defined under the SCPI Standard.

Commands and Queries

SCPI Common Commands

The SCPI Standard specifies a standard set of common commands. All common commands and queries start with an asterisk.

Reset Command - *RST

Resets all operational parameters to their power-on states. Reset does not affect factory settings. Also see "Reset Command - *RST" on page 56.

Command: *RST
Query: none

Identification Query - *IDN?

Queries the sensor identification string, such as model name, firmware version, and firmware date.

Query: *IDN?
Reply: "Coherent, Inc – PowerMax" + <type> + "–" + <version> + "–" + <firmware date> *Note: The quotes are not transmitted*.

Example reply: Coherent, Inc – PowerMax-USB – V1.3 – Jul 10 2009

System Options

The system commands and queries access functionality that is exclusive of sensor measurement functions. These commands can be sent at any time without affecting a measurement in progress.

System Status

Queries the system status. Status is returned in a string containing one ASCII character for each status condition that is asserted. If the status condition character is present, the condition is asserted. If the status condition character is absent, the condition is not asserted. The following table describes the status condition character mapping.

Table 6. Status Condition Character Definitions

STATUS CHARACTER	STATUS CONDITION
T	Damage temperature is exceeded
0 (zero)	No status condition is asserted

Command: none

Query: SYSTem:STATus?
Reply: <status>

Example: If the sensor damage temperature is exceeded, the system status query will return:

"T" *Note: The quotes are not transmitted*.

Sensor Temperature

Queries the sensor temperature.

Command: none

Query: SYSTem:INFormation:TEMPerature?
Reply: <sensor temperature in degrees Celsius in integer format>

The literal string "NA" (quotes not included) is returned if the sensor does not have a temperature measurement capability.

System Sync

Resets the system measurement sync timer. This query gets the system measurement sync timer value. The system measurement sync timer is a free-running timer that increments by one for every 1 millisecond of elapsed time. It is necessary to synchronize the measurement sync timers of all sensors that are used for applications requiring synchronization. The maximum value of this timer is 4294967295 milliseconds; however, to counteract clock creep, the system sync command should be sent at intervals not to exceed 10 minutes.

Command: SYSTem:SYNC

Query: SYSTem:SYNC?
Reply: <current timer value>

Message Handshaking

Selects the state of SCPI message round trip handshaking.

Command: SYSTem:COMMunicate:HANDshaking {ON|OFF}
Reply: OK if ON is selected; otherwise, no reply is sent

Default is OFF.

Query: SYSTem:COMMunicate:HANDshaking?
Reply: ON|OFF

If handshaking is ON:

- Empty commands (commands with only whitespace characters) reply with "OK\r\n"

- Valid commands with valid data reply with “OK\r\n”
- Valid queries with valid data reply as explicitly defined elsewhere in this section, followed by “OK\r\n”
- Valid commands or queries which result in an error reply with “ERR<n>\r\n”, where <n> is the error code number (see “Error Record Reporting and Collection” on page 58).
- Unrecognized commands or queries reply with “ERR100\r\n”
- Error queuing occurs, as explicitly defined elsewhere in this document

If handshaking is OFF:

- All command and query response will behave as explicitly defined elsewhere in this section

Error Record Reporting and Collection

Programming and system errors occasionally occur while testing or debugging remote programs, and during measurement. Error strings follow the SCPI Standard for error record definition:

<error code>,<quoted error string>

The host queries for errors in two steps:

1. The host queries for the number of error records available (N).
2. The host queries N times for the error records.

Errors are stacked up to 20 deep. In the case of error overflow, the last error in the error list is an indication of error overflow.

The possible error strings are shown in the following table.

Table 7. Error Codes and Description Strings

ERROR CODE NUMBER	QUOTED ERROR STRING	ERROR DESCRIPTION
-350	“Queue overflow”	Error queue is full
-310	“System error”	Unexpected/unrecoverable hardware or software fault
0	“No error”	No error
100	“Unrecognized command/query”	The command or query is not recognized
101	“Invalid parameter”	The command or query parameter is invalid
102	“Data error”	A data error was encountered

Error -350 is raised when the error queue becomes full. Non-"Queue overflow" errors are replaced by "Queue overflow" errors when there is exactly one available storage location available in the error queue. No additional errors are added to the error queue if the error queue is full.

Error -310 is raised when the firmware detects an unexpected or unrecoverable error. This error condition includes unrecoverable hardware faults.

Error 100 is raised when the sensor receives an unrecognized command or query.

Error 101 is raised when the sensor receives a command or query with one or more invalid data parameters.

Error 102 is raised when the sensor receives a command or query for which no valid data exists.

Error Count Query

Queries the number of error records in the error queue at the time of the query.

Command: none

Query: SYSTem:ERRor:COUNt?
Reply: <count of error records stored in integer format>

Error Query

Queries the next error record(s) in the error queue. More than one error record may be queried using the optional <error record count> parameter, which must be an integer value. A single error record is returned if <error record count> is not specified. No reply is transmitted if no error records are available.

As the sensor transmits each error record:

- The error record is permanently removed from the error queue
- The queued error record count decrements by one

Command: none

Query: SYSTem:ERRor:NEXT? [<error record count>]
Default is not applicable.
Reply: <next available error record(s)>

All Error Query

Queries all error records in the error queue at the time of the query. No reply is transmitted if there are no error records available.

After completion of the reply transmission:

- The error queue will be empty
- The queued error record count will be zero

Command: none

Query: SYSTem:ERRor:ALL?
Reply: <all available error record(s)>

All Error Clear

Clears all error records in the error queue.

Command: SYSTem:ERRor:CLEar

Query: none

Measurement Setup and Control

Measurement Mode

Sets the sensor measurement mode to select either power (Watts) or energy (Joules) measurement mode. Note: Joules measurement mode is only possible with a thermopile type power sensor.

Command: CONFigure:MEASure {DEFault|J|W}
Default is W (Watts) mode.

Query: CONFigure:MEASure?
Reply: J|W

Error 100 is raised if the sensor is an optical sensor.

Speedup

Sets the speedup state. The query gets the speedup state.

Command: CONFigure:SPEedup {DEFault|ON|OFF}
Default is OFF

Query: CONFigure:SPEedup?
Reply: {ON|OFF}

Error 100 is raised if the sensor is an optical sensor.

Wavelength

Sets the current wavelength, which is committed to persistent storage when it is changed. If the requested wavelength is *greater* than the upper wavelength limit, the current wavelength is set to the upper wavelength limit. Likewise, if the requested wavelength is *less* than the lower wavelength limit, the current wavelength is set to the lower wavelength limit. The minimum and maximum allowed

wavelength may also be named as data arguments. The query gets the current maximum or minimum allowed wavelengths, depending on the optional query data argument.

Command: CONFigure:WAVElength {MINimum|
MAXimum|<requested wavelength in nm>}

Query: CONFigure:WAVElength? [MINimum|
MAXimum]
Reply (*if [MINimum|MAXimum] is not specified*):
<granted wavelength in nm>
Reply (*if MAXimum is specified*):
<allowed maximum wavelength in nm>
Reply (*if MINimum is specified*):
<allowed minimum wavelength in nm>

Gain Compensation

Enable/Disable State

Enables or disables gain compensation, which is committed to persistent storage when it is changed. If gain compensation is enabled, power readings sent over the host port will be measured power multiplied by the gain compensation factor.

Command: CONFigure:GAIN:COMPensation {DEFault|OFF|ON}
Default is OFF

Query: CONFigure:GAIN:COMPensation?
Reply: OFF|ON

Factor

Sets the gain compensation factor, which is committed to persistent storage when it is changed.

Command: CONFigure:GAIN:FACTor {DEFault|
<0.001..100000.0>}
Default is 1.0

Query: CONFigure:GAIN:FACTor?
Reply: <gain compensation factor>

Sensor Zero

Sets the current measurement as the zero baseline measurement. We recommend that you zero the sensor prior to measuring power to null out any offset in the power sensor. If you have recently touched a thermopile or exposed it to heat, you must wait for the sensor to settle back to a stable zero point before sending the Zero command.

Command: CONFigure:ZERO

Pulsed Thermopile Joules Trigger Level

Selects the pulsed thermopile Joules mode trigger sensitivity level.

Command: TRIGger:PTJ:LEVel {DEFault|LOW|MEDium|HIGH}
Default is LOW

Query: TRIGger:PTJ:LEVel?
Reply: LOW|MEDIUM|HIGH

Querying Measurement Data

Queries the last recorded measurement at the time of the query. No reply is transmitted if a measurement has not been recorded.

Command: none

Query: READ?
Reply: <last measurement record>

The last measurement record is composed of comma-delimited data items generated at the same instant. The data items presented, including a flags item, varies, depending on the sensor type as enumerated in the following table.

Table 8. Measurement Data Record Formats

SENSOR TYPE	MEASUREMENT MODE	LAST MEASUREMENT RECORD FORMAT
Thermopile Mono (PM-model thermopiles, like PM-10)	Watts	<power>,<flags>,<timestamp>
	Joules	<energy>,<flags>,<timestamp>
Thermopile Quad (LM-model thermopiles, like LM-10)	Watts	<power>,<X position>,<Y position>,<flags>,<timestamp>
	Joules	<energy>,<flags>,<timestamp>
Optical	Watts	<power>,<flags>,<timestamp>

<power> will be expressed in Watts using the "%.5E" C formatting specification.

<energy> will be expressed in Joules using the "%.5E" C formatting specification.

<X position> and <Y position> will be expressed in mm using the "%.2E" C formatting specification.

<timestamp> will be expressed in integer milliseconds. This timestamp is based upon the system sync function. Zero time is set when the device receives the SYSTem:SYNC command.

The <flags> data item, which communicates qualification information, is reported with each data message. Qualification information—including various error conditions—is reported in a string

containing one ASCII character for each qualification that is asserted. If the qualification character is present, the qualification is asserted. If the qualification condition character is absent, the qualification is not asserted. Each character present has a unique meaning, as described in the following table.

Table 9. Flags Character Definitions

QUALIFICATION CHARACTER	QUALIFICATION MEANING
R	Over-range error
N	Negative power
S	Measurement is sped up
T	Over-temperature error
0 (zero)	No qualification exists

Note that X and Y positions are zero if the power is less than 10% of the minimum range.

Note that the data has over-range status if the power is greater than the maximum range.

Sensor Information

The sensor can be queried for unit identification and quality control information.

Serial Number

The query gets the sensor serial number.

Query: SYSTem:INFormation:SNUMber?
Reply: <quoted serial number>

Calibration Date

The query gets the calibration date.

Query: SYSTem:INFormation:CDATe?
Reply: <quoted calibration date>

Manufacturing Date

The query gets the manufacturing date.

Query: SYSTem:INFormation:MDATe?
Reply: <quoted calibration date>

Sensor Type and Connection Configuration

The query gets the sensor type and connection configuration (thermopile mono, thermopile classical quad, thermopile enhanced quad, or optical).

Query: SYSTem:INFormation:TYPE?
Reply: <type>,<qualifier>

<type> is one of THERMO or OPT.
<qualifier> is one of SINGLE, QUAD, ENHQUAD, or NOSPEC.

Aperture Diameter

The query gets the aperture diameter.

Query: SYSTem:INFormation:DIAMeter?
Reply: <aperture diameter in mm>

Default Wavelength

The query gets the default wavelength.

Query: SYSTem:INFormation:WAVElength?
Reply: <default wavelength in nm>

Legacy LaserPAD/SSIM Interface Section

PowerMax-USB and PowerMax-RS sensors support the legacy LaserPAD/SSIM host command sets. This offers customers the capability of using PowerMax-USB And PowerMax-RS sensors as drop-in replacements for their current OEM sensors. The LaserPAD/SSIM interface supports all LaserPAD/SSIM commands, queries, and responses, except those related to PocketPC mode.

Commands and Queries

Note that some LaserPAD/SSIM commands also have defined replies.

Help Query

Queries the list of LaserPAD/SSIM commands.

Query: h
Reply:

“*rst - reset system
*ind - identify system
app - get aperture diameter
cal - get calibration date
df? - get family
dsp - stop data streaming
dst - start data streaming
dt? - get name
h - show this help
mfg - get manufacture date
pos - get x,y position in mm
pw? - get power in watts
rmi - get minimum range
rmx - get maximum range
sn? - get serial number
tmp - get thermistor reading
v? - get firmware version
vp? - get protocol version
wl? - get default wavelength
wv <float> - set current wavelength in meters
wv? - get current wavelength in meters
spd - toggles speedup state on/off
spd? - queries the speedup state” *Note: The quotes are not transmitted*.

Reset Command

Resets all operational parameters to their power-on states. Reset does not affect factory settings. (Also refer to “Reset Command - *RST” on page 56.)

Command: *rst
Reply: none

Hardware Description Query

Queries the hardware description.

Query: *ind
Alias query: dt?
Reply: "PowerMax" + <type> *Note: The quotes are not transmitted*.

Example reply: PowerMax USB

Firmware Version Query

Queries the firmware version.

Query: v?
Reply: <the firmware version string>

Data Stream Protocol Version Query

Queries the data stream protocol version.

Query: vp?
Reply: “v.12.10.03” *Note: The quotes are not transmitted*.

Serial Number Query

Queries the serial number.

Query: msn?
Alias query: sn?
Reply: <serial number>

Calibration Date Query

Queries the calibration date.

Query: mcal?
Alias queries: cal and cal?
Reply: <calibration date>

Manufacturing Date Query

Queries the manufacturing date.

Query: mfg
Alias query: mmfg?
Reply: <manufacturing date>

Sensor Family Query

Queries the sensor family.

Query: df?
Reply: {“thermal”|“quantum”} *Note: The quotes are not transmitted*.

Aperture Diameter Query

Queries the aperture diameter, a fixed value.

Query: app
Reply: <aperture diameter in mm>

Minimum Range Query

Queries the minimum range.

Query: rmi
Reply: <minimum allowed power measurement in watts>

Maximum Range Query

Queries the maximum range.

Query: rmx
Reply: <maximum allowed power measurement in watts>

Speedup State Query

Queries the speedup state.

Query: spd?
Reply: {“on”|“off”} *Note: The quotes are not transmitted*.

Speedup State Toggle Command

Toggles the speedup state. If the speedup state is ON, sending the command turns speedup OFF, and vice versa.

Command: spd
Reply: {“speedup threshholding is on.”|“speedup threshholding is off.”} *Note: The quotes are not transmitted*.

Default Wavelength Query

Queries the default wavelength.

Query: wl?
Reply: <default wavelength in meters>

Current Wavelength Query

Queries the current wavelength.

Query: wv?
Reply: <current wavelength in meters>

Current Wavelength Command

Sets the current wavelength, which is committed to persistent storage when it is changed. If the requested wavelength is greater than the upper wavelength limit, the requested wavelength is set to the upper wavelength limit. Likewise, if the requested wavelength is less than the lower wavelength limit, the requested wavelength is set to the lower wavelength limit.

Command: wv <requested wavelength in meters>
Reply: <granted wavelength in meters>

Current Power Reading Query

Queries the current power reading.

Query: pw?
Reply: <current power reading in watts>

Current Beam Position Query

Queries the current beam position. If the sensor is an optical sensor, the returned position X and Y values are 0.

Query: pos
Reply (*thermopile quad sensor*): <X position in mm>,<Y position in mm>
Reply (thermopile mono or optical sensor): 0,0

Note that X and Y positions are zero if the sensor is a thermopile mono or if the power is less than 10% of the minimum range (see “Minimum Range Query” on page 67).

Current Thermistor Counts Query

Queries the current thermistor ADC value.

Query: tmp
Reply: <thermistor integer ADC counts>

Start Data Streaming Command

Enables LaserPAD/SSIM mode interface data streaming. Streaming data records are transmitted at 10 Hz. Streaming data records continue to be transmitted until the Stop Data Streaming command (see below) is issued.

Command: dst
Reply: none

Stop Data Streaming Command

Disables LaserPAD/SSIM mode interface data streaming.

Command: dsp
Reply: none

LaserPAD/SSIM Streaming Data Record Format

The LaserPAD/SSIM mode streaming data record format is different for thermopile and optical sensors, as shown in the following table.

Table 10. Measurement Data Record Formats

SENSOR TYPE	LAST MEASUREMENT RECORD FORMAT
Thermopile	*<X position in mm>,<Y position in mm>,<power in watts>,<status code>
Optical	*<power in watts>,<status code>

Note that the data has over-range status if the power is greater than the maximum range.

Status code:

c = Measurement data is valid

r = Measurement is over-range

t = Sensor temperature exceeds the damage temperature

Power string output uses the “%.3e” formatting specification. Position string output uses the “%.2e” C formatting specification.

Data Streaming Transmission Interface Section

The data streaming transmission interface should not be confused with legacy LaserPAD/SSIM mode interface data streaming. Gating of the data streaming transmissions is controlled by the INITiate and ABORt commands (described under "Initiate Command" and "Abort Command," below).

Streaming Measurement Data

In data streaming mode, the host has control over when measurement data is transmitted from the data streaming transmission interface. Transmission is enabled after an INITiate command and disabled after an ABORt command. When transmission is enabled, measurement data records are transmitted immediately as they are generated.

Commands and Queries

Initiate Command

Enables data streaming interface transmission. This command is ignored if data streaming interface transmission is already enabled.

Command: INITiate

Query: none

Abort Command

Disables data streaming interface transmission. This command is ignored if data streaming interface transmission is already disabled.

Command: ABORt

Query: none

Data streaming transmission messages are ASCII formatted, but not strictly so. The high bit (mask 0x80) is always set for all bytes of all data streaming transmission messages, including the terminators. This allows host software to easily differentiate between data streaming transmission messages and LaserPAD/SSIM and SCPI reply messages. The host may operate using the rule that if the high bit is set on any byte received from the sensor, it is part of a data streaming transmission message.

Data streaming transmission messages are immediately sent to the host in ASCII text form as measurements are generated (see Table 11, below). Each message conforms to the last measurement data record format—described under "Querying Measurement Data" on page 62—but with the high bit set in all transmitted bytes.

Table 11. Data Streaming Transmission Rates

SENSOR TYPE	MEASUREMENT MODE	TRANSMISSION RATE
Thermopile	Watts	Continuously at 10 Hz
Thermopile	Joules	When pulse energy is calculated
Optical	Watts	Continuously at 10 Hz

Operational Parameters

All operational parameters—except the current wavelength, gain compensation factor, and gain compensation state—are not persistent after a reset cycle. The following table shows all operational parameters.

Table 12. Operational Parameters

PARAMETER	POWER-ON STATE
Speedup state	Off
Measure Mode	Watts
Error count	0
LaserPAD/SSIM data streaming state	Stopped/Disabled
Data streaming transmission interface state	Stopped/Disabled
Sync	0
SCPI handshaking	Off
Zero	Factory setting
Pulsed thermopile Joules mode trigger sensitivity level	Low
Accuracy mode	Power-plus-position
Current wavelength (persistent)	Last granted setting
Gain compensation factor (persistent)	Last setting
Gain compensation state (persistent)	Last setting
Wavelength correction cursor	0/start
Temperature compensation cursor	0/start
Power compensation cursor	0/start

CALIBRATION AND WARRANTY

In this section:

- Calibration (this page)
- Coherent calibration facilities and capabilities (this page)
- Limited warranty (page 74)
- Extended warranty (page 74)
- Warranty limitations (page 75)
- Obtaining service (page 75)
- Product shipping instructions (page 76)

Calibration

Coherent laser power and energy meters are precision instruments, capable of delivering very accurate measurements, as well as providing many years of useful service. To maintain this high level of performance, it is important to have your measurement system serviced and recalibrated once a year.

Coherent Calibration Facilities and Capabilities

As the largest laser manufacturer in the world, Coherent has been able to build state-of-the-art calibration facilities containing the widest possible range of laser types and technologies. This enables us to perform instrument and sensor calibration under virtually any combination of wavelength, power, and operating characteristics. Sensors are calibrated against NIST-traceable working standard sensors which are, in turn, calibrated against NIST-calibrated golden standard sensors. These working and golden standards are maintained with the utmost care, recalibrated annually, and verified even more regularly. We maintain multiple NIST-calibrated standards at many laser wavelengths to support the growing calibration needs of our customers. Optical calibration is a core competency at Coherent and we strive to continually improve our methods, precision, and repeatability. Additionally, most of the calibrations are performed with highly automated systems, thus reducing the possibility of human error to nearly zero. Strict quality inspections during many stages of calibration and testing assure a precise and accurate instrument that is NIST traceable and CE marked. The benefit to our customers is that instruments calibrated by Coherent will consis-

tently perform as expected under their actual use conditions. We are a registered ISO 9001:2000 company, our products are NIST traceable, and our calibration labs are fully ANSI Z540 compliant.

In addition to the technological advantage, we also strive to deliver the best service in the industry, with a knowledgeable and responsive staff, and rapid turnaround.

Limited Warranty

Coherent, Inc. (the "Company") warrants its laser power and energy meters and sensors products ("Products") to the original purchaser (the "Customer") that the product is free from defects in materials and workmanship and complies with all specifications, active at the time of purchase, for a period of twelve (12) months.

Coherent, Inc. will, at its option, repair or replace any product or component found to be defective during the warranty period. This warranty applies only to the original purchaser and is not transferable.

Extended Warranty

Coherent, Inc. (the "Company") offers original purchasers (the "Customer") purchasing laser power and energy meters and sensors products ("Products") an extended twelve (12) month warranty program, which includes all parts and labor. In order to qualify for this warranty, a Customer must return the Product to the Company for recalibration and recertification. The Company will recertify the Product, provide software upgrades, and perform any needed repairs, and recalibrate the Product, for a fixed service fee (as established by the Company from time to time and in effect at the time of service). If the product cannot be recertified due to damage beyond repair, parts obsolescence, or other reasons, the Customer may be informed that an Extended Warranty program is not available for the Product.

If the Product fails and is returned to the Company within one year following the date of recalibration and recertification service, the Company will, at its option, repair or replace the Product or any component found to be defective. If the Product must be replaced and the Product is no longer available for sale, Coherent reserves the right to replace with an equivalent or better Product. This warranty applies only to the original purchaser and is not transferable.

Warranty Limitations

The foregoing warranties shall not apply, and Coherent reserves the right to refuse warranty service, should malfunction or failure result from:

- Damage caused by improper installation, handling or use.
- Laser damage (including sensor elements damaged beyond repair).
- Failure to follow recommended maintenance procedures.
- Unauthorized product modification or repair.
- Operation outside the environmental specifications of the product.

Coherent assumes no liability for Customer-supplied material returned with Products for warranty service or recalibration.

THIS WARRANTY IS EXCLUSIVE IN LIEU OF ALL OTHER WARRANTIES WHETHER WRITTEN, ORAL, OR IMPLIED. COHERENT SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL THE COMPANY BE LIABLE FOR ANY INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH ITS PRODUCTS.

Obtaining Service

In order to obtain service under this warranty, Customer must notify the Company of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. The Company shall, in its sole discretion, determine whether to perform warranty service at the Customer's facility, at the Company's facility or at an authorized repair station.

If Customer is directed by the Company to ship the product to the Company or a repair station, Customer shall package the product (to protect from damage during shipping) and ship it to the address specified by the Company, shipping prepaid. The customer shall pay the cost of shipping the Product back to the Customer in conjunction with recalibration and recertification; the Company shall pay the cost of shipping the Product back to the Customer in conjunction with product failures within the first twelve months of time of sale or during an extended twelve month warranty period.

A Returned Material Authorization number (RMA) assigned by the Company must be included on the outside of all shipping packages and containers. Items returned without an RMA number are subject to return to the sender.

Table 13. Coherent Service Centers

LOCATION	PHONE	FAX	E-MAIL
USA	1.800.343.4912	503.454.5777	info_service@coherent.com
Europe	+49-6071-968-0	+49-6071-968-499	info_service@coherent.com
International	503.454.5700	503.454.5777	info_service@coherent.com

Product Shipping Instructions

To prepare the product for shipping to Coherent:

1. Contact Coherent Customer Service (refer to Table 13 on page 76) for a Return Material Authorization number.
2. Attach a tag to the product that includes the name and address of the owner, the person to contact, the serial number, and the RMA number you received from Coherent Customer Service.
3. Wrap the product with polyethylene sheeting or equivalent material.
4. If the original packing material and carton are not available, obtain a corrugated cardboard shipping carton with inside dimensions that are at least 6 in (15 cm) taller, wider, and deeper than the product. The shipping carton must be constructed of cardboard with a minimum of 375 lb (170 kg) test strength. Cushion the instrument in the shipping carton with packing material or urethane foam on all sides between the carton and the product. Allow 3 in (7.5 cm) on all sides, top, and bottom.
5. Seal the shipping carton with shipping tape or an industrial stapler.
6. Ship the product to:

   Coherent, Inc.
   27650 SW 95th Ave.
   Wilsonville, OR 97070
   Attn: RMA # (*add the RMA number you received from Coherent Customer Service*)

APPENDIX A: SPECIFICATIONS

The following table presents a list of available PowerMax-USB and PowerMax-RS sensors, current as of the publication date of this manual. For an up-to-date list of all compatible sensors and their specifications, visit out website: www.Coherent.com/LMC.

Compatible Sensors

Table 14. Compatible Sensors

	UV/VIS	PS19Q	LM-3	LM-10	LM-45	PM10-19C	PM150-19C	PM150-50C
Wavelength Range	325 to 1065 nm	300 to 2100 nm	0.25 to 10.6 µm	0.25 to 10.6 µm	0.25 to 10.6 µm	0.19 to 11 µm	0.19 to 11 µm	0.19 to 11 µm
Power Range	10 µm to 100 mW (@ 1064 nm)	100 µW to 1W	10 mW to 3W	10 mW to 10W	100 mW to 25W	10 mW to 10W (water-cooled)	300 mW to 150W (water-cooled)	300 mW to 150W (water-cooled)
Max. Intermittent Power (W) (< 5 min.)	N/A	3	10	12	45	5 (air-cooled)	20 (air-cooled)	80 (air-cooled)
Long-Pulse Joules (J)	N/A	0.001 to 1	0.5 to 10	0.5 to 10	0.5 to 50	0.5 to 10	1 to 150	1 to 150
Noise Equivalent Power	100 nW	3 µW	0.4 mW	0.4 mW	2 mW	0.2 mW	1 mW	1 mW
Max. Power Density	20 W/cm^2	500 W/cm^2	6 kW/cm^2	6 kW/cm^2	6 kW/cm^2	6 kW/cm^2	6 kW/cm^2	6 kW/cm^2
Max. Energy Density (mJ/cm^2)	N/A	50 10 ns, 1064 nm	600 10 ns, 1064 nm	600 10 ns, 1064 nm	600 10 ns, 1064 nm	600 10 ns, 1064 nm	600 10 ns, 1064 nm	600 10 ns, 1064 nm
Sensor Coating	N/A	Black	Broadband	Broadband	Broadband	Broadband	Broadband	Broadband
Sensor Element	Silicon photodiode	Thermopile	Thermopile	Thermopile	Thermopile	Thermopile	Thermopile	Thermopile
Optic	ND2	Quartz	None	None	None	None	None	None
Sensor Diameter (mm)	10	19	19	16	19	19	19	50
Calibration Uncertainty (%)	± 2	± 2	± 2	± 2	± 2	± 2	± 2	± 2
Power Linearity (%)	± 1	± 1	± 1	± 1	± 1	± 1	± 1	± 1
Spectral Compensation Accuracy (%)	± 4 (325 to 900 nm) ± 5 (900 to 1065 nm)	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5
Long-Pulse Joules Accuracy (%)	N/A	± 3	± 3	± 3	± 3	± 3	± 3	± 3
Calibration Wavelength (nm)	514	514	10600	10600	10600	10600	10600	10600
Cooling Method	Air	Air	Air	Air	Air	Water Air (intermittent)	Water Air (intermittent)	Water Air (intermittent)
Cable Type	USB	USB	USB	USB	USB	USB and RS	USB and RS	USB and RS
Cable Length (m)	2.5	2.5	2.5	2.5	2.5	2.5 (USB) 0.3 (RS)	2.5 (USB) 0.3 (RS)	2.5 (USB) 0.3 (RS)
Part Number	1168337	1168343	1168339	1168340	1168342	1168344 (USB) 1168345 (RS)	1168346 (USB) 1168347 (RS)	1168348 (USB) 1168349 (RS)

APPENDIX B: TROUBLESHOOTING AND ERROR MESSAGES

The PowerMax PC application crashes or is forced to quit

If the application crashes or is forced to quit, PowerMax sensors connected to the computer may not properly release from remote mode.

To clear the issue: Disconnect and then reconnect the USB cable on each of the affected sensors.

An error message displays when the last sensor is removed

The PowerMax PC application displays a communications error if all PowerMax sensors s are removed from the computer while the application is running. This error message serves as a reminder that there are no sensors available for data collection.

To clear the error: Select **OK** in the error window(s). Reconnect the sensor to the computer and then click the **Select Sensor** button to continue.

An error message displays when a sensor is removed while acquiring data

The PowerMax PC application displays error windows if a sensor is removed while that sensor is streaming data. Data collection should be stopped before removing a sensor that is being used to collect data.

To clear the error: Select **OK** in the error window(s). Reconnect the sensor to the computer and then click the **Select Sensor** button to continue; or, select **File**, then **Exit**, to exit the software.

Failed communications error

The PowerMax PC application displays an error if a communications failure occurs while reading sensor parameters.

To clear the error: Click the **OK** button.

INDEX

C
Cable length, extending 12
Calibration 73
Coherent calibration facilities and capabilities 73
Compliance
    RoHS vii
    U.S. export control laws vii

D
Data streaming transmission interface 70
Declaration of Conformity 2

E
Error messages 79
Extended warranty 74

F
Features
    Product 3
    Software 4
File menu 40
Front panel 19

H
Help menu 49
Host command quick reference 53
Host interface 51
    Data streaming transmission interface 70
    Host command quick reference 53
    Legacy LaserPAD/SSIM interface 65
    Message terminators 52
    Operational parameters 71
    SCPI interface 55

I
Interface
    Data streaming transmission 70
    Host 51
    Legacy LaserPAD/SSIM 65
    SCPI 55

L
LED status indicators 11
Legacy LaserPAD/SSIM interface 65
Limited warranty 74

M
Menu
    File 40
    Help 49
    Settings 45
    View 47
    Window 49
Message terminators 52
Messages
    Received by the sensor 52
    Sent by the sensor 52

O
Operating the software 11
Operational parameters 71

P
Power measurements, taking 13
Preface vii
Product
    Features 3
    Overview 3
    Shipping instructions 76
Publication updates vii

Q
Quick reference, host command 53

R
RoHS compliance vii
RS sensors, powering 12

S
Safety 1
    Declaration of Conformity 2
    Waste Electrical and Electronic Equipment (WEEE, 2002) 1
SCPI interface 55
Semiconductor technology 7
Service, obtaining warranty 75
Settings menu 45
Shipping instructions, product 76
Software
    Features 4
    Front panel 19
    Menus 40
Specifications
    Compatible sensors 77
Status indicators, LED 11
Symbols used in this document vii

T
Technology
    Semiconductor 7
    Thermopile 5
Terminators, message 52

Thermopile technology 5
Troubleshooting 79

U
U.S. export control laws compliance vii

V
View menu 47

W
Warranty
    Extended 74
    Limitations 75
    Limited 74
    Obtaining service 75
Waste Electrical and Electronic Equipment (WEEE, 2002) 1
Wavelength, setting 18
Window menu 49

Z
Zeroing 18

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